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Vol. I. JANUARY, 1896. No. 1.

The Digest
OF
Physical Tests
AND
Laboratory Practice.

A résumé of Practical Tests made in the Laboratories of the World.

JOSEPH W. BRAMWELL, EDITOR.

PUBLISHED QUARTERLY
BY
FREDERICK A. RIEHLÉ,
1424 North Ninth Street, Philadelphia, Pa., U. S. A.

Telegraphic address from all parts of the world, "RIEHLÉ PHILADELPHIA."

Entered, according to Act of Congress, in the year 1895, by FREDERICK A. RIEHLÉ,
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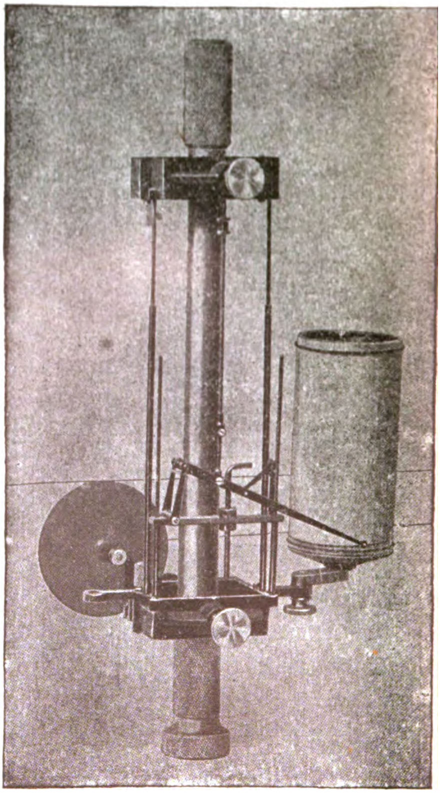

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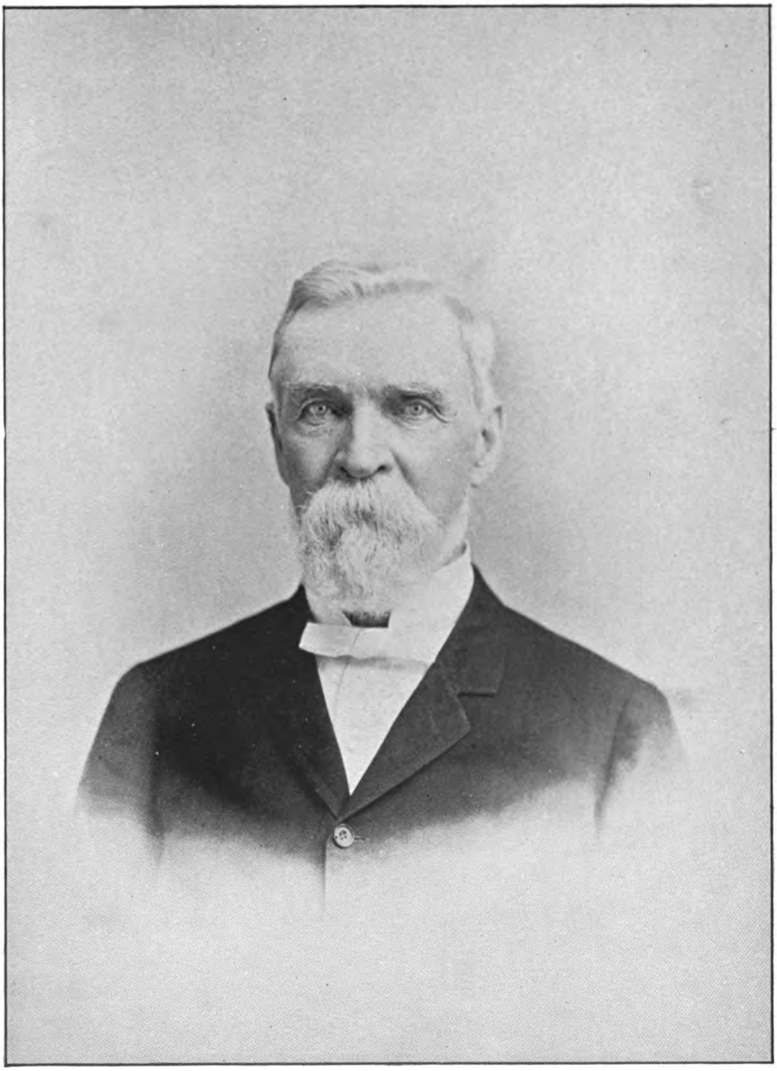

Yours Truly
John Fitz

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Digest of Physical Tests.

A RÉSUMÉ OF PRACTICAL TESTS MADE IN THE
LABORATORIES OF THE WORLD.

Vol. I. JANUARY, 1896. No. 1.

THE STRENGTH OF ENGINEERING MATERIALS.

A NEW SCIENCE.

BY J. B. JOHNSON,
Professor of Civil Engineering, Washington University, St. Louis, Mo.

The permanent commission of the French Government charged with supervising and directing the work of the government laboratories in their studies of the strength of Engineering Materials has recently issued a quarto volume of 143 pages, containing a bibliography of the more recent investigations on the strength of materials of construction. It needs only a casual glance at the list of names and subjects herein recorded to convince one of the wide extent and thoroughness of the inquiries now being prosecuted in the most scientific manner in this inviting field of investigation. In every civilized country on the globe laboratories have been established, and in many places liberally endowed, while in others they are lavishly supplied with government aid, all of them laboring toward the common end of a fuller knowledge of the nature of the materials of construction. The mathematical and mechanical sciences of engineering practice being logical and deductive in their nature can be developed very largely by the mathematician in his study. It is but natural, therefore, that this groundwork of engineering science should have been developed far in advance of its necessary complement, which consists of a knowledge of the properties of the materials which must be used to resist the action of the forces which the science of mathematics and mechanics fully reveals. This latter kind of knowledge can only be obtained by long, patient, and expensive experiments with the most scientific apparatus, on the various kinds of engineering materials, in all possible forms of their application. It may fairly be said that only within the last twenty-five years has this kind of scientific information been adequately sought. It is only within such a short period of time that suitable testing machines and appliances have been in use for the purpose of adequately determining these properties. In the same period of time, however, many materials of construction have undergone a revolutionary change in their characteristics, especially the steels and the alloyed metals. Because of this advancing change in the materials of construction themselves, therefore, laboratory investigations of their properties will always be required to enable our knowledge of the same to keep pace with the improvements in the methods of manufacture, and the corresponding improvements in the products. As yet, however, we have scarcely begun to determine accurately and scientifically the constant properties of the more ordinary materials of construction which are constant in their nature, and so the work to be done by these laboratories has been but fairly commenced. In this country there are scores of testing laboratories, mostly connected with technical schools, which are occasionally engaged in original investigations, the results of which are not now published, however important and valuable they may be. In addition to the work of these collegiate and the many private or commercial laboratories we have the one large testing machine at the United States Arsenal, Watertown, Mass. This machine is constantly engaged in investigations of an important character, results of which are published in an annual volume, but these volumes are not generally accessible. Besides the work of this one machine the government is also engaged in carrying on the most elaborate series of investigations on the strength of timber which has ever been undertaken, the published reports of which are given a very wide circulation. Some 40,000 tests of timber have now been made, under the direction of the writer, for the Forestry Division of the United States Agriculturul Department, and these will eventually all be published and made accessible to any one who cares to apply for them. With this exception, however, very little of the work of our many testing laboratories now finds its way in accessible form to the men who most need such information, while the extremely valuable investigations which are being carried out abroad, and especially in Germany, are now quite inaccessible to most American readers.

Engineers do not need to be told that the greatest progress now making in engineering science, and the greatest progress to be made in the next quarter of a century, lies in the direction of a further knowledge of the properties of engineering materials. Unless the knowledge gained in these various testing laboratories, however, is adequately circulated amongst engineers and architects, no corresponding professional progess can result. The publishing of the results of the tests in both our home and foreign laboratories, therefore, in a quarterly journal devoted especially to this end, should meet the enthusiastic approval of the entire profession. It is to be hoped that the support given to this new venture will be such as to enable the publishers to include in it all the more significant results of experiments carried out in any part of the world. I know of no single undertaking better calculated to advance the interests of the engineering profession at this time than the collection, translation, and publication, with a suitable reduction to the American units of pounds per square inch, of the more important work of this kind now being carried out and published abroad. If to this be added such work of American laboratories as has permanent value, the publication would at once become a fixed and necessary part of the literature of the profession.

It seems to be assumed by many that any one is competent to devise and execute experiments intended to develop the strength of engineering materials for resisting the action of various kinds of loads. As a matter of fact, however, no one is competent either to devise or to carry out such experiments who is not thoroughly trained in those departments of mathematical and mechanical science relating to this subject. It is for this reason that the results attained in the laboratories connected with the technical schools of Germany are so much more reliable than many of those which have been made and published in this country. The utter confusion, contradiction, and mystification which may result from a series of tests erroneously conceived and inadequately executed has been well illustrated more than once in this country in the near past. Under such circumstances "there is nothing so false as facts, and nothing can lie like figures." It is to be hoped, therefore, that such a publication as is now proposed will have so competent an editorial supervision as to serve as a guarantee of the reliability of such results as are published in it.

. The scores of published volumes issued in Germany, giving the results of the most carefully conducted tests on the strength of materials of all kinds, which for many years have been carried out at Berlin, at Munich, and at Zurich, together with the volumes giving the proceedings of the various international commissions on the strength of materials, are all practically unknown in this country. It is of the highest importance that the work of such men as the late Professor Bauschinger, of Munich, and of Professor Tetmajer, of Zurich, should become better known here. As a single illustration of the work of the latter experimenter, the Swiss government, on his recommendation, some twelve years ago, adopted in its specifications for structural steel, the product of the ultimate strength per square inch into the ultimate elongation, as fixing the standard of acceptance of such material. This standard has recently been adopted also in the Austrian governmental specifications, and is commonly used in Germany. Just as the valuable qualities of cast iron for all ordinary uses is best determined by the product of the ultimate strength of a cast-iron beam into its deflection, divided by the volume or weight of the beam,* so the working qualities of structural iron or steel is best determined by the area of the strain diagram obtained by plotting a complete tensile test. But the area of this diagram is a very nearly constant portion of the rectangle obtained by multiplying the ultimate strength by the ultimate elongation. If the ultimate strength per square inch be multiplied by the percentage of elongation from a test on a specimen of standard dimensions, this product becomes a constant characteristic of the material, while the strength and the elongation may vary inversely through wide limits. If this product, therefore, be made the criterion of acceptance rather than either the strength or elongation taken separately, or both combined, a wider range of these individual results might safely be used, provided their product remained practically constant.

The study of the strength of engineering materials could not be placed upon a scientific basis until scientific instruments of investigation had been placed upon the market. Machines for making all kinds of tests for the strength of materials have now been brought to such a degree of perfection that little or nothing further can be desired in this direction, and it only remains to set these machines to work, under scientific direction, to obtain results equally scientific, free from error, and of permanent value.

---

*Recommended by the writer many years ago and now very commonly employed.

With the practically perfect instruments of investigation now found in the laboratory outfit of every good engineering school, and the great number of young men annually graduated from these schools, thoroughly trained on both the theoretical and practical sides of this subject, the progress of this, the newest of the sciences, will hereafter be very rapid. With no longer any recognized conflict between theory and practice in this, any more than in any other established science, and with the instruments of investigation in the hands of the makers of the formulæ, so that both theoretical and practical knowledge will hereafter come at first hands to the same individuals, we may confidently anticipate that before many years all our formulæ used in designing will represent actual facts, and all the facts of experiments will be adequately recognized and formulated in all the standard text and hand-books. Already we see a tendency on the part of the practicing members of the engineering profession to look to the schools for those experimental and practical facts and constants to be used in designing, while, on the other hand, the teachers of engineering in the schools are coming to be almost exclusively men who have had a greater or less amount of actual experience in practice. The new science of the strength of materials, therefore, is being developed by men who first either from mathematical or mechanical considerations predict a fact which they afterward prove experimentally, or they determine the facts experimentally, and afterward devise adequate theories to account for them, and suitable formulæ to utilize them. So long as one class of men were looked to for the theories and the formulæ, and an entirely different class of men were relied upon for the facts of engineering, little or no substantial progress could be made, and the so-called conflict between theory and practice seemed real and necessary. When, however, these two phases of the same question find place in the mind of the same individual, he cannot endure a standing logical contradiction in his own mind, and hence he will continue to struggle with the question until he has succeeded in harmonizing his theories with his demonstrated facts. The establishment of testing laboratories, therefore, as a component part of the outfit of every engineering school, marks the beginning of a new era in engineering science. It now only remains to find a suitable means of publication of the results of permanent value determined in these numerous laboratories to complete the conditions of an ideal progress in this new and inviting field.

TESTS OF CEMENT MORTAR MIXED WITH VARIOUS KINDS OF SAND.*

BY A. S. COOPER,
U. S. Assistant Engineer.

During the construction of a mining casemate at Fort Pulaski last year, the question arose as to the advisability of using fine beach sand instead of coarse river sand, on account of the greater cost in obtaining the latter. The writer took the position that the fine sand would be nearly as good, in fact good enough, and as its employment was estimated to save at least $1,000 in the total cost of the work, a short series of experiments was made, which to the astonishment of all connected with the work, proved the fine sand to be slightly stronger than the coarse. These results were spoken of as being opposed to those obtained by all previous experimenters, and this fact induced the author to investigate the question in a more thorough and scientific manner.

The first matter to be settled was the method of working in order to eliminate as many uncertainties as possible. Where close figures are to be expected, a slight inaccuracy in the work might lead to erroneous conclusions. After looking over all of the different methods, the following were finally adopted as being the most suitable for this work.

Methods of Conducting the Work.—The sand was first graded by means of thirteen sieves, ranging from eight to 140 wires to the lineal inch, and the grades indicated by the two sieves used. The grade 8–12, for example, means that the sand in this grade passed a sieve with eight wires to the inch, and was held by one with twelve wires. It was concluded to mix the mortar rather dry, about the consistency of moist snow, so as to be able to handle the briquettes immediately after molding them. It was also believed that a dry mortar would give more even results under uniform pressure than a wet one. The sand and cement were first carefully weighed, then they were mixed dry by means of a square box with a rod run through the corners, after the manner of General Q. A. Gillmore's concrete mixer.

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* Extracts from *Journal Franklin Institute*, Vol. CXL, No. 5.

The water was measured with a graduated glass, and mixed into the cement and sand on a stone table with a trowel. If the mortar appeared too dry, more water was added; and if too wet note was made of the fact, and the set proceeded with. In nearly all cases enough mortar was made at one mixing to make eight briquettes. Four of these were broken at the end of a week, and the remainder in eight weeks. As a difference of one per cent. of water in the finished mortar, could not, in all cases, be detected, a series of tests was made to determine the effect of such variations. The results proved conclusively that slight variations in the amount of water might cause considerable differences. In drawing conclusions, therefore, the percentage of water used must be considered.

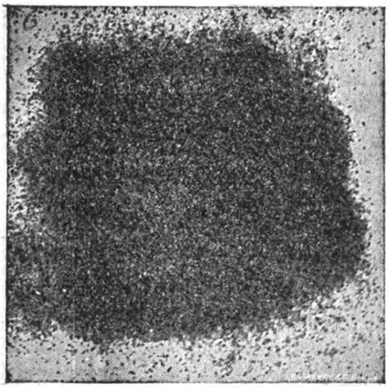
It should also be borne in mind that some cements and some sands of the same size require more water than others to yield a mortar of the same consistency. Generally speaking, fine sand requires more water than coarse, and natural cements more than Portlands. The briquettes were molded in brass molds of the form recommended by the Committee of the American Society of Civil Engineers, in 1885, but were not pressed in by hand as recommended by this committee. The method used by Prof. Charles D. Jameson was adopted. Prof. Jameson put his mortar into the molds under a uniform pressure of 150 pounds per square inch, while in this work 200 pounds were used. The press consisted of a simple lever arranged in such a manner that when pressure was applied nothing but vertical pressure would be transmitted to the briquette. The pressure was applied by putting a constant weight on the end of the lever. A set of tests was made with varying pressures obtained by a longer lever than the one used for the main work, to see what would be the effect of the different pressures. Although the effect of an increase of pressure is quite marked, yet slight changes sometimes even doubling the pressure have very little effect. As soon as taken from the press the briquettes were removed from the molds, placed on a stone slab, and covered with a wet cloth, where they remained for twenty-four hours, when they were immersed in water for the required time. The briquettes were broken with a Fairbanks machine of 1,000 pounds capacity, and the strain was applied at the rate of about 300 pounds per minute.

In order to compare the general accuracy of this work with that of other operators, the writer has constructed a table of results, shown herewith, from three other sources, in all of which the methods recommended by the American Society of Civil Engineers were used. It will be seen that the results obtained by the writer are at least as accurate as those of Colonel Poe, a circumstance which he attributes to the better methods he employed. In this table the greatest difference of any one briquette from the mean of the set was used, and this

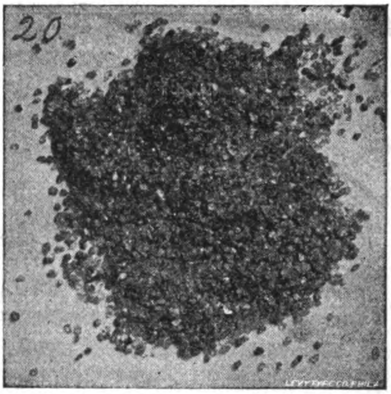
TABLE OF RELATIVE ACCURACY OF EXPERIMENTERS.

NAME OF EXPERIMENTER.	CEMENT USED.	PARTS OF SAND TO 1 OF CEMENT.	TESTS.			DIFFERENCE FROM MEAN.		PER CENT. OF MEAN DIF. WITH MEAN STRAIN.
			Age.	No. of Sets.	No. in each Set.	Greatest.	Mean.	
Goddard and Ewans,	Natural	1	7	1	10	13	13	101
" "	"	1	56	1	10	20	20	19
" "	Portland	3	7	1	10	28	28	44
" "	"	3	56	1	10	29	29	17
Abbott and Morrison,	"	1	7	2	7	48	27	12
" "	"	1	60	2	7	44	42	15
" "	Natural	1	7	1	8	11	11	25
" "	"	1	60	1	8	4	4	5
Colonel Poe, . . .	Portland	1	7	1	5	19	19	6
" . . .	"	1	28	1	10	17	17	4
" . . .	"	1	3 mo.	1	5	19	19	3
" . . .	"	1½	7	1	10	29	29	6
" . . .	"	1½	28	1	10	87	87	15
" . . .	"	1½	3 mo.	1	10	76	76	10
" . . .	"	2	3 mo.	5	5	57	35	6
" . . .	"	3	7	1	5	9	9	6
" . . .	"	3	28	8	5	32	16	6
" . . .	Natural	2	28	3	7	17	12	6
" . . .	"	2	3 mo.	10	5	36	25	8
" . . .	"	1	7	3	5	24	14	16
" . . .	"	1	28	3	5	68	34	14
" . . .	"	1	3 mo.	2	5	54	37	9
A. S. Cooper, . . .	"	1	7	122	4	13	3½	9
" . . .	"	1	56	135	4	34	10	10
" . . .	Portland	1	7	82	4	28	11	7
" . . .	"	1	56	104	4	60	16	7
" . . .	"	2	7	5	4	16	8	10
" . . .	"	2	56	5	4	17	11	8

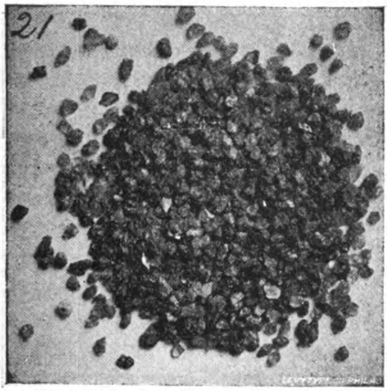
difference divided by the mean strain of the set, to get the percentage of error. Where more than one set was given the mean of all these differences was divided by the mean of all the strains. The greatest difference in any one set is also given, but the percentage is figured from the mean. No attempt was made to secure a uniform tempera-



RIVER SAND.
Size, 70-80.



RIVER SAND.
Size, 20-30.



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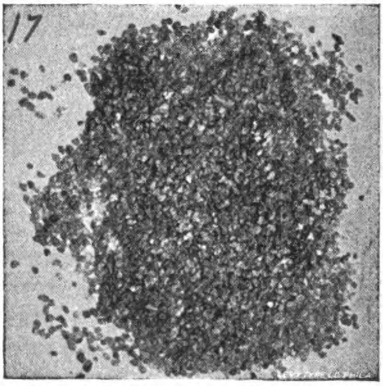

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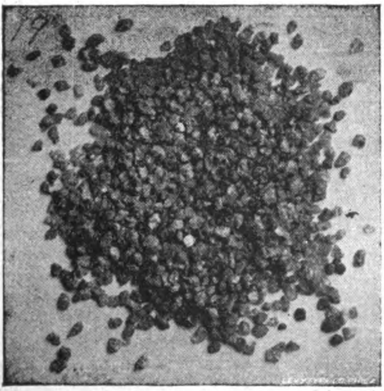

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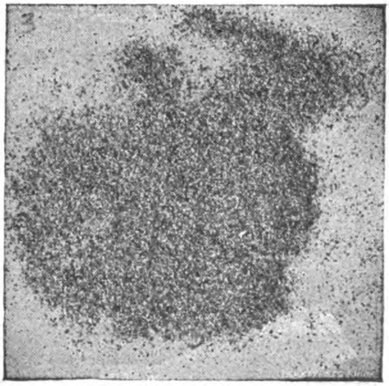
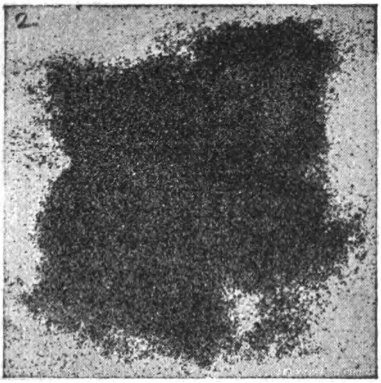
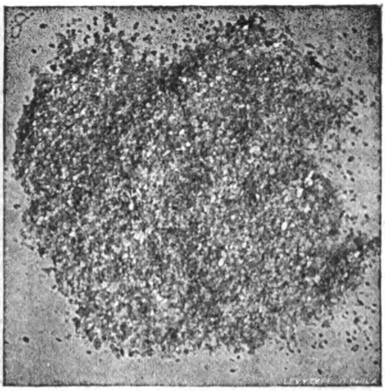


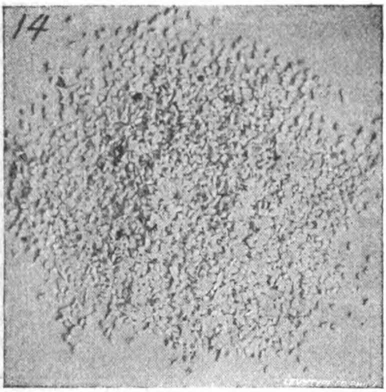
COCKSPUR BEACH.
Size, 70-80.



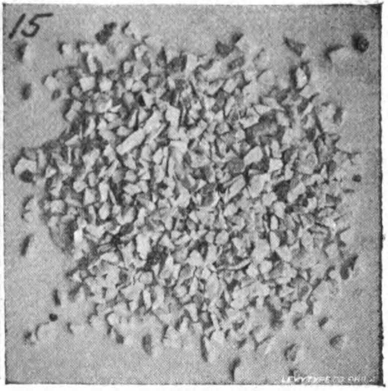
AUGUSTA, No. 2.
Size, 120-140.



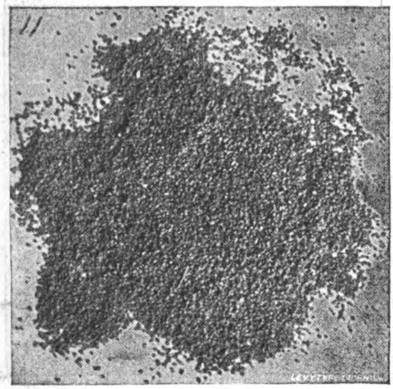
AUGUSTA, No. 2.
Size, 30-40.



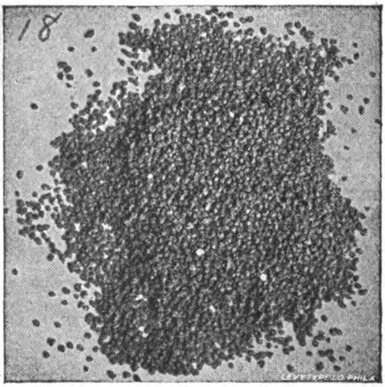
FLORIDA LIMESTONE.
Size, 20-30.



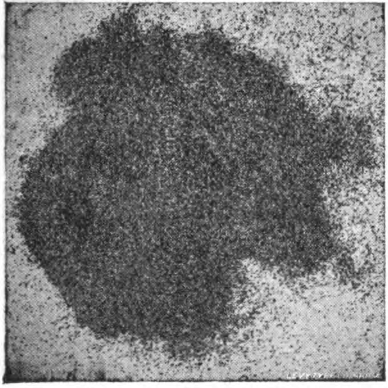
FLORIDA LIMESTONE.
Size, 12-16.



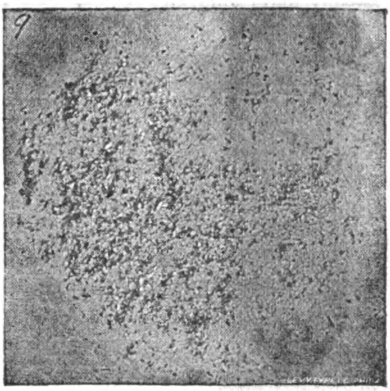
RED SANDSTONE.
Size, 30-40.



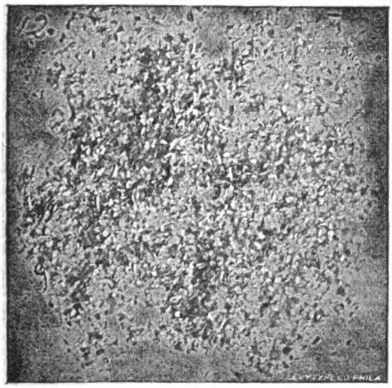
RED SANDSTONE.
Size, 20-30.



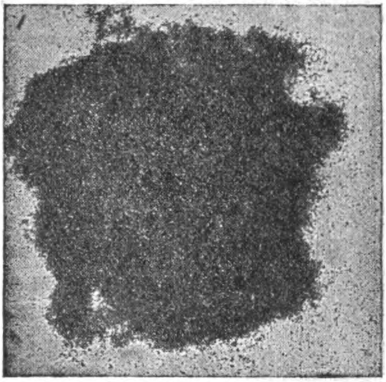
CUMBERLAND QUICKSAND.
Size, passed 140



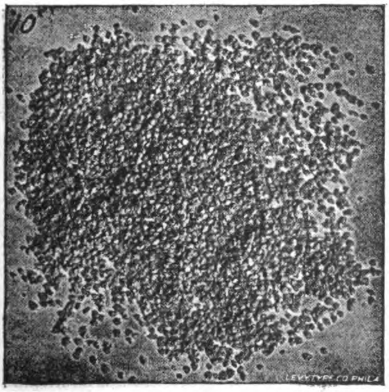
CUMBERLAND QUICKSAND.
Size, 40-50.



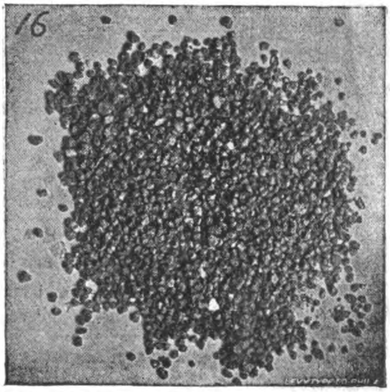
CUMBERLAND QUICKSAND.
Size, 30-40.



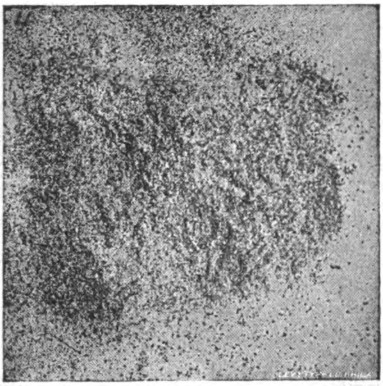
BROWN SANDSTONE.
Size, 120-140.



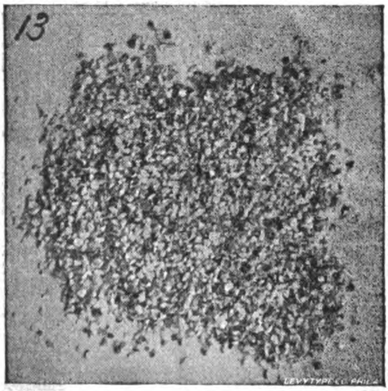
BROWN SANDSTONE.
Size, 20-30.



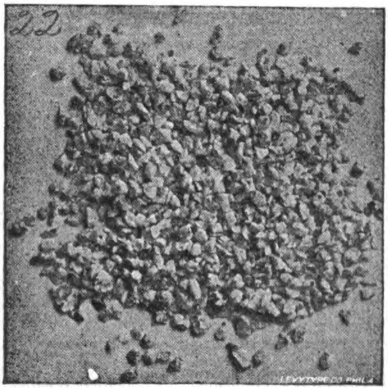
BROWN SANDSTONE.
Size, 16-20.



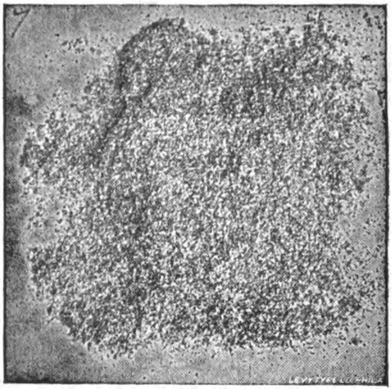
GRANITE.
Size, 80-100.



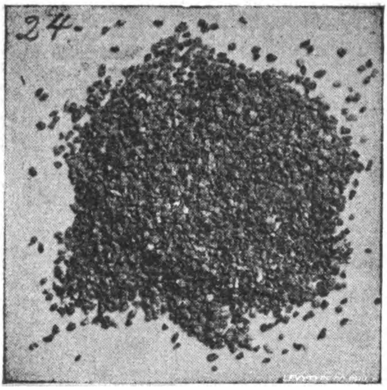
GRANITE.
Size, 20-30.



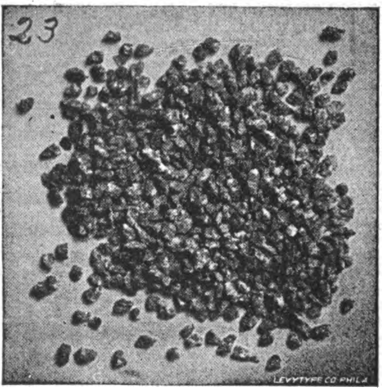
GRANITE.
Size, 12-16.



TRAP ROCK.
Size, 70-80.



TRAP ROCK.
Size, 20-30.



TRAP ROCK.
Size, 12-16.

ture, but in nearly all cases each series of tests was made on the same day, so that each set in each series was subjected to the same temperature.

The illustrations shown herewith comprise three grades of each sand. They have been reproduced to natural size, in all cases from a photograph of the material itself, in order to give a better idea of the comparative shape and size of grain of each sand than could be obtained from a description.

Results.—Generally speaking, the coarser the sand the stronger the mortar made from it; but the difference between the grades below 30–40 are so slight that, as far as sizes are concerned, they might be considered in one class. There seemed to be a tendency toward an increase in strength with grades below 100–120, but so few samples of these grades were obtained that this slight increase may be put down as accidental. There is an unmistakable indication of weakness in the upper grade, 8–12. In the tables, about two cases out of three give 12–16 as stronger than 8–12; and there is but one case where 8–12 is the highest, that cannot be accounted for by there being more water in this grade than in the next one. The shape and condition of the surface of sands, however, has much to do with the strength. The Florida rock, which broke up into the sharpest sand of all, was not as good as some of the natural sands, probably owing to extremely smooth surfaces. Trap rock was not as sharp as the Florida rock, but gave much better results on account of the surfaces of the grains being very rough. The granite was about the same as the trap rock. The comparison of the beach and river sands, with but few exceptions, has proven the latter to be the best for cement mortar by from to 2 to 10 per cent. After the grade of 40–50 is reached in the river sands, there is no practical difference between them and the beach sands. These two sands were compared by taking equal parts of sand and cement, by measure, and the result was the same as when taken by weight. The first set of experiments, in which it was found that the beach sand was the best, was unquestionably wrong; and there is no way of explaining how such a result was obtained. Greater ratios than 1 to 1 were tried mainly to test these two sands, and the difference was found to be less noticeable. Colonel Poe, in his work, found differences, due to different kinds of sand, to be greatest in mortar where the least cement was used, and, as he did more work in that line than the writer, he may be right. The ratio of 1 to 1 was chosen for this work, however, on the supposition that it was the best for the purpose intended.

The only other series in the same line as the body of this work, that the writer could find to compare with, was that of Mr. Paul Alexandre, chief engineer of roads and bridges, France, published in *Annales des Ponts et Chaussees*, 1892. His results, as far as they go, are the same as those here recorded except that his upper grade proved to be the maximum. This grade contained average grains a little coarser than the writer's upper grade, but also had a greater range of sizes; besides, the next lower grade was considerably smaller than the writer's second grade. The lowest grade was about equal to the writer's 50–60 grade, and, in the light of the present results, was quite low enough.

It is apparent that the specific gravity of all of the various kinds and grades of sand tried are not materially different, and that, therefore, the difference found between the weights of equal volumes are principally due to the different percentages of voids. It is further apparent that the smaller the grade the greater the percentage of voids in loose sand, and *vice versa;* while in well packed sand there is practically no difference in percentage of voids. These results indicate that the uniformity of mortar briquettes for tests can be obtained only by either measuring the sand while well packed, or by weighing.

Conclusions.—(1) Other things being equal, coarse sands are better than fine sands for cement mortar up to the grade 12–16, or about one-twelfth of an inch in diameter. (2) Below the grade 40–50, or about one-sixtieth of an inch in diameter, there is no practical difference in the value of the different sands, as far as the size is concerned. (3) The shape and condition of the surfaces of the grains of different sands has as much to do with their value for cement mortar as the size.

WE are pleased to mention that the first subscriber to the QUARTERLY DIGEST was Chief of Bureau of Steam Engineering, George W. Melville, U. S. N., the second, Director Frank C. Hatch, Department of Mechanical Engineering, Armour Institute, Chicago, Ill., and the third on the list Dr. R. H. Thurston, Director Sibley College, Cornell University, Ithaca, N. Y.

THE INSPECTION AND TESTING OF MATERIALS.

BY ALFRED P. BOLLER.

With the vast development of Constructive Engineering during the last twenty-five years has arisen the necessity for a thorough knowledge of the strength of materials, to be gained only from actual experiment. As increasing knowledge always opens vistas of the unknown, the testing of materials has grown from simple methods of procedure into an elaborate scientific system of means and methods, calling into play various apparatus of power and precision. This has given rise to a class of specialists who make a business of testing and inspecting materials, and to a branch of mechanical engineering devoted to the designing and manufacture of testing machines and various recording devices. No important work is now undertaken without careful provision for testing all materials which enter into it, and under specifications evolved from the recorded experience of experimenters continually at work throughout the civilized world. With the improvements of apparatus, new light on the behavior of materials under varying conditions is continually obtained, and specifications are from time to time modified accordingly. Few railways of any importance are without a testing bureau in charge of careful experimenters. To these bureaus are brought samples of all sorts of materials required in the conduct and maintenance of a railway, and upon the bureau report of quality, application, and endurance the standards are determined and specifications for purchase issued accordingly. Minor railways and other corporate and private interests are served by various testing laboratories and testing bureaus established in the different centres of manufacturing and engineering activity.

The result of such a close watch over constructive material has been to force manufacturers into scientific modes of manufacture and to pay close attention to quality and uniformity of product as the price of their very existence. Such work has made possible the great engineering triumphs of the day, in which the humble testing machine has played a no inconsiderable part. While the time has passed when testing and inspection of materials was regarded as a luxury or an engineer's fad by "the financial interest," there is a tendency to incite too much competition among the laboratories, resulting, in many cases, in a price for services and the use of machines below what such work can be efficiently performed. The consequence is, the testing is not thorough and inspection perfunctorily gone through with, resulting in unreliable reports. In this business, like any other, work and services are worth all they cost, plus a reasonable profit, and it is no evidence of business smartness on the part of an employer to beat down rates and prices below which he can get efficient service. If done at all, testing and inspection should be thoroughly done, or it is worse than useless, as it is misleading in creating a confidence on a basis that does not exist. No money is better invested in public or private work on which life depends than that paid in carefully looking after it, to see that it is well done, of good materials for the purpose, and efficiently made and put together.

WHERE IGNORANCE IS BLISS.

There seems to be a prevalent idea that, even if it is not quite right to impose upon the ignorance of our fellow-men, we are, at least, sometimes justified in so doing. It is doubtful if a much more striking illustration of this could be had than is pointed out in the following conversation, which was accidentally overheard in a Philadelphia freight office:

"John, what's all those barrels you're pilin' up in the yard?"

"That's the stuff wot come for the —— building."

"Well, why don't you send it roun'? They'll be wantin' it."

"Did, but they wouldn't have it."

"Why not?"

"Condemned—no good."

"Well, what you're goin' to do with it? We can't have it standen roun' here."

"I dunno, but I heard the boss say something about as he was going to send it to ——, as they don't make no tests there."

THE International Conference on Standard Tests, held a few months ago at Zurich, Switzerland, was attended by over 300 delegates, and the record of its proceedings covers 1,200 printed pages.

AN AUTOGRAPHIC TESTING-MACHINE ATTACHMENT.

BY THOMAS GRAY,

Professor Dynamic Engineering, Rose Polytechnic Institute, Terre Haute, Ind.

The importance of obtaining more complete information as to the properties of the materials used in construction than is given by the usual tests is now very generally recognized. We have evidence of the interest taken in this subject in the large number of testing-machine attachments that have of late years been tried. Most of these have for their object the provision of means by which the relation of the elongation of the specimen to the force producing it can be more accurately observed than it can be by direct measurement on the specimen. Some of these attachments are designed to give autographic records of the relation between the force and the change of dimensions, while others provide in various ways for making a series of separate observations of the load and the corresponding change of dimensions or shape. This latter method has some advantages when great sensitiveness is desired, but the observations are tedious, and in some cases the time required to make the observation produces a serious disturbing element in the test. This is the case, for example, with materials like wood or cast iron where the rate of loading has an important influence on the form of the curve of elongation. The effect of the rate of loading on the relation between the load and the elongation, or other distortion, produced by it is one of the most interesting subjects in the study of the properties of materials. For this study, however, autographic apparatus is the most suitable. Not only because it gives a permanent record, but because it shows all the fluctuations, whether of long or short duration, which take place. A good example is given by the behavior of iron or steel near the yield point when under tension test. The character of the curve may be entirely changed near this point by changing the rate of loading. Then again the relation between load and elongation is subject to such rapid fluctuations near the yield point that measurements by other than autographic means are practically useless so far as showing the curve of relation is concerned.

Recognizing the great advantage, for many purposes, of the autographic method, the present writer began, about six years ago, the attempt to produce an apparatus for the purpose which would give, accurately and with considerable magnification, the changes of dimension produced by the load. The object was simply to obtain apparatus for personal use in experiments on the properties of materials. The first difficulty which presented itself was to provide in the same apparatus for tests both on the elastic properties and on the flow of the material after it began to take permanent set under the load. Some combination which will attain this object is desirable, so that data both for elasticity and variation of strength with permanent flow may be accurately obtained from specimens tested for commercial purposes. The simplest solution seemed to be the provision of a double recording system, worked by the same attachment on the specimen, one part giving such a magnification of the elongation or compression that the elastic properties could be studied with a fair degree of accuracy from the diagram, while the other part should give on a moderately enlarged scale a complete record of the test. The details of this scheme were worked out in a variety of ways, and several sets of apparatus have been made and tried. The principal point to be determined was how much magnifying power could be given to the parts of the apparatus designed for the study of the elastic properties without sacrificing accuracy in the record. Experience has shown that with proper appliances the magnification may be made at least one thousand without introducing any serious difficulty or sacrificing anything as to the reliability of the record due to friction or yielding of some part of the apparatus. This range is greater than is required even when ordinary commercial test pieces of six or eight inches length are used in the investigation. In the earlier forms of the apparatus the higher magnifying set gave a record one hundred times as great as the actual stretch of the specimen.

This was found too small for some purposes, and the later sets of apparatus provide for several different values of the magnifying power, one thousand being taken as the upper limit. Two forms of the apparatus have been used, differing only in the method of making the record. In one the pen is carried directly on the end of one of the levers of the recording apparatus and draws an arc of a circle in the record sheet, while in the other the pen is fixed in a carriage which moves between guides and is lifted by means of a parallel motion arrangement, formed by the magnifying levers of the recording system. This parallel motion device is omitted in the diagram given below, the pen being supposed guided by the slides alone. Such an arrangement would serve the purpose, but would be somewhat frictional. The degree of magnification possible when the pen is not guided to move in a straight line is almost unlimited, because it is easy to arrange a perfectly frictionless recording device, by means of a vibrating pen, for example, and the frictional resistance of knife-edge bearings can be made vanishingly small. Such a set of apparatus is not however suitable for commercial work, and the curved co-ordinates are inconvenient.

The principle of the apparatus may be gathered from the diagrams, Figs. 1 and 2, which show approximately the arrangement of the apparatus. These figures and the description of them is taken, with only slight changes, from the *Proceedings of the American Society of Mechanical Engineers*, Volume XIII. The apparatus, as now in use in the mechanical laboratory of the Rose Polytechnic Institute and as made by Riehlé Bros. differs from this only in the form and arrangement of some of the parts.

Referring to Figs. 1 and 2, *M M* are the two grip crossheads of one of Riehlé's testing machines of the Harvard type. The lower of these crossheads is adjustable in height by means of two screwed rods (one on each side of the grip), which connect the crosshead to the piston of the hydraulic apparatus used for applying the stress to the specimen. To the upper crosshead a beam, *P*, is bolted, and on the top of this beam the recording apparatus is mounted and enclosed in a case. The outer end of the beam *P* is braced by means of stay rods from the lower part of the platform, carried by the steelyard levers of the machine, so that any distortion of the crosshead does not affect the record. To the specimen *A* two frames of the form shown in the figure are pivoted at *d* and *g* of the main diagram and at *B* in the detail (Fig. 2) *. The bars *b b* are round, with the exception of the central block, and are made long enough to allow the side bars to be separated far enough to enclose the largest specimen which the machine is intended to test. The pivots are held firmly in two centre-punch holes by means of two flat springs, to which the ends of the chains *a a* are attached. This makes a form of frame which is very easily put in position on the specimen, and which is at the same time rigid in the

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* It is better not to pivot the frames directly to the specimen, as here shown, but to pivot two blocks to the specimen with the line of pivots at right angles to those of the frames and allow the frames to bear through knife edges on these blocks.

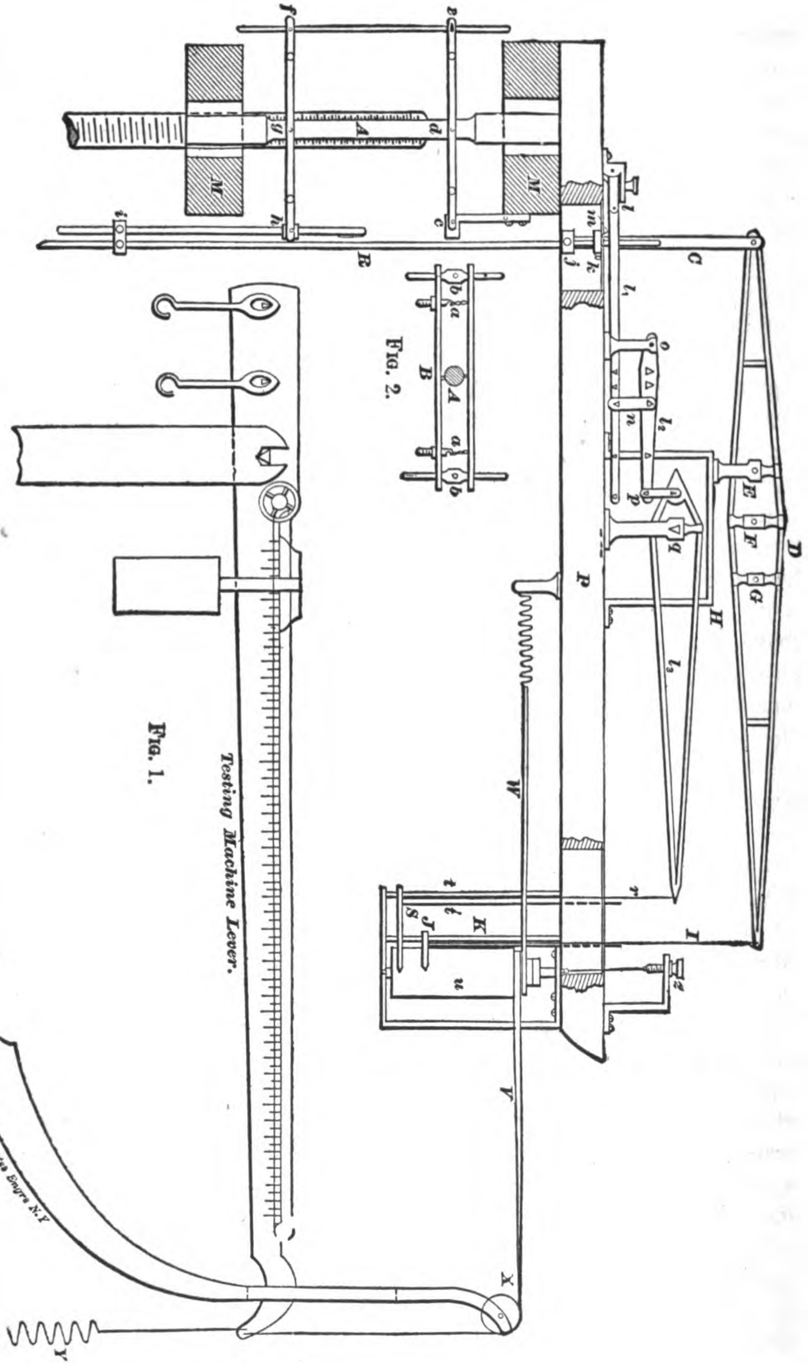

FIG. 2.

FIG. 1.

Testing Machine Lever.

direction of the forces applied to it. The pivots being placed across a diameter of the specimen, and the recording apparatus worked from the centre of the end bars of the frames, insures that bending of the specimen will produce little effect on the diagram. The upper of these two frames is pivoted at *c* to a link* hinged to the upper crosshead *M*, then to the specimen at *d*, and finally to a rigid rod, acting as a strut between the two frames, at *e*. The lower frame is hinged at *f* to the strut connecting the two frames, is pivoted to the specimen at *g*, and carries on its free end a link *h i*, which connects it to the vertical rod *R*. The length of the link *h i* is the same as the length from *e* to *f* of the strut connecting the ends of the two frames, so that if *g* moves relatively to *a* the rod *R* will move just twice as much without any error due to the arcs round which the points *f* and *h* turn. The block at *i* is rigidly fixed to the rod *R*, but is pivoted to a second block, which is clamped on the link, so as to give the necessary freedom of motion. The rod *R* slides in guide blocks fixed to the machine near the upper and lower ends of the rod. It is evident that by clamping the frames at the proper distance apart on the rod *e f*, any length of specimen may be used. It will be readily seen, also, that since the point *c* is practically fixed relatively to the machine, the point *h* will also be fixed so long as the specimen does not change length, and therefore slipping in the grips does not affect the record. If, however, the specimen stretches, the rod *R* will move down through a distance equal to twice the change of length between the points *d* and *g*.

The record of the elastic elongation of the specimen is made by means of the system of levers l_1, l_2, l_3. The left-hand end of the lever l_1 is pivoted to a hinged piece, *l*, which can be raised or lowered by means of a screw so as to adjust the position of the record pen. Passing from the hinged piece *l*, the lever l_1 rests through a knife edge and a vertical strut, *m*, on a block, *k*, clamped to the rod *R*, and its forward end is carried by the lever l_2, to which it is connected by the link *n*. The lever l_2 rests by a knife edge on the supporting pillar at *o*, and its forward end is carried by the lever l_3, which it helps to counterpoise. The lever l_3 rests by a knife edge bearing on a pillar at *q*, and carries on its forward end a pen, *s*, which is connected to the lever by a light thread. The pen *s* consists of a very small ink-well, furnished with a capillary opening opposite the paper on which it writes. This pen is carried on the end of an arm, s, and is guided to move vertically by means of the fixed rod t and a light rod t^1 fixed to s and guided at its upper end. The length of the supporting thread r is made about in the same ratio to that of the link p as the ratio of the long to the short arm of the lever l, allowance being made for the motion of l_2. In the set of apparatus from which the diagram was sketched the ratio of the arms of the lever l_3 is 10 to 1, but by changing the position of the link n the combined ratio of the other two levers may be made either 5, 10, 15, 20, or 25 to 1, thus enabling the magnification of the record to pass from 100 times to 500 times by convenient steps. This amount of magnification is found amply sufficient for any ordinary material if the specimen be a few inches in length, the observations on a specimen 8 inches long being equivalent to direct observation on a bar 330 feet long. It will be noticed that the method of attachment here described allows the block k on the rod R to move away from the strut m, and thus to leave the sensitive system of levers unaffected by elongations beyond the range of the diagram. Immediately permanent set and flow of the material sets in, the pen s moves suddenly up against a stop on the rod t, and the levers are unaffected by the subsequent stretching. The very beginning of the permanent set is thus obtained with great accuracy.

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* Shown as a rigid piece in the drawing in which case the axis *c* works in a slot.

The permanent elongation of the specimen is recorded by means of the lever D, which is connected to the rod R by means of the connecting rod C, and rests on a round axis at E or F or G, according to the scale of the diagram desired. The first of these positions for the axis magnifies the elongation four times, the second three times, and the third two times. This lever produces its record by means of a pen, j, which is precisely similar to s. With regard to the dimensions of the parts, it may be stated that in the apparatus now being used at the Rose Polytechnic Institute the lever D is four feet long. The shortest lever arm in the whole apparatus is thus about two inches, a length which can be measured with considerable accuracy even if no direct method of standardizing the system could be adopted. The long levers are made of light, hard-steel rods, and have a form similar to that shown in the diagram, which insures a very light and yet rigid system.

The record is made on a sheet of paper wound on the drum u. This drum is pivoted on straight bearings at top and bottom, and its weight is carried by a thin steel wire attached to the adjusting screw z.

The drum thus turns very freely, and care is taken to arrange the driving apparatus to insure little or no pressure on the bearings. The drum is provided with two sets of double pulleys of different sizes placed near the upper end of the axis. Supposing, as shown in the diagram, the larger set to be in use, a silk, or a thin steel, tape is placed on each pulley, and the end of one of these tapes carried over the pulley x and attached to the end of the testing machine lever through a special slip grip arrangement not shown in the diagram. The other tape w is attached to the end of a light spring capable of elongating by an amount equal to the circumference of the pulley. These two tapes pulling against each other in the same plane produce very little pressure on the axis. The position of the end of the machine lever is controlled by a spring of the proper strength, the elongation of which by the pull on the specimen under test causes the drum to revolve in proportion to the stress applied. The horizontal scale of the diagram is thus proportional to the strength of the spring y, and this scale is usually obtained by comparing the vertical motion of the pen for a pull on the specimen measured by the sliding steelyard weight with the motion of the pen for any convenient displacement of the drum round its axis when controlled by the spring. For standardizing tests of this sort a hard steel bar is placed in the machine so as to avoid trouble due to "set" during the test. The stresses indicated by the instrument are thus the same as those which would be obtained by testing with the sliding weight. It will be observed that provision is made in this form of the apparatus for producing a diagram to rectangular coördinates. This is the chief difference between the apparatus here described and that which I have used for several years in which the pens were attached directly to the ends of the levers.

When materials are tested for crushing strength or for elasticity under compressing forces, the specimen is placed below the lower crosshead m, which is then pulled down on it, producing compression between the crosshead and the sole plate of the balanced part of the machine. A longer link has then to be used to make the connection to the point c, or, as is found rather more convenient, the bar $e\ c$ is placed below, and a strut connection made to the sole plate instead of the link to the upper crosshead. The method of obtaining the diagram is otherwise identical with that already described.

This apparatus has been used by the writer principally for instruction purposes in connection with his classes in the mechanical laboratory, but several branches of investigation are more or less advanced in which it has been used. Some parts of these investigations illustrative of the records obtained will be given in a future number of this paper.

THE RESISTANCE OF MATERIALS UNDER IMPACT.

In an address before the American Association for the Advancement of Science, Mr. Mansfield Merriman said that during all the development of static testing one impact test has survived and everywhere held its own. This is the cold-bend test for wrought iron and steel. In the rolling mill it is used to judge of the purity and quality of the muck bar; in the steel mill it serves to classify and grade the material almost as well as chemical analysis can do, and in the purchase of shape iron it affords a quick and reliable method of estimating toughness, ductility, strength, and resilience. It is true that numerical values of these qualities are not obtained, but the indications are so valuable that if all tests except one were to be abandoned, the simple cold-bend test would probably be the one which the majority of engineers would desire to retain.

STRENGTH OF GLASS.

Traulionie gives the tensile strength of glass at from 2,500 to 9,000 pounds per square inch, according to kind; crushing strength, 6,000 to 10,000 pounds per square inch; transversely, by his own trials, Millville, N. J., flooring glass, one-inch square, and one foot between the end supports, breaks under a certain load of about 170 pounds, consequently it is considerably stronger than granite, except as regards crushing, in which the two are about equal. It is suggested that glass will shortly be used for many purposes where other and much inferior materials are still exclusively employed. Glass may be used as water conducts to better advantage than cast iron or terra cotta, as it is impervious to moisture and proof against corrosion or chemical action. It is already considerably in use for flooring, and it has lately been successfully experimented with for railway sleepers under exceptionally severe conditions.

JOHN FRITZ.

A NOTED CAPTAIN OF INDUSTRY.

BY J. F. HOLLOWAY.

Through the courtesy of *Cassier Magazine*, we are enabled to present the portrait and following biographical sketch of Mr. John Fritz, America's veteran engineer and newly elected President of the Am. Soc. Mech. Engrs.—Ed.

As a conspicuous example of the change in public opinion, and in the drift of modern thought, may be cited the fact that the men now in the foremost place in the esteem and admiration of an intelligent public, are not, as in the long ago, the diplomats, warriors, poets, and statesmen, but rather the men who, in the arts and sciences, and especially as engineers, inventors, and artisans, have, by their work, helped forward the material progress of their own country, and have aided as well in bringing civilization with its numerous blessings into a broader diffusion, and have distributed its benefits over a wider circle of the human race.

The Wizard of the North, whose works charmed the readers of a past generation, has been eclipsed by the brighter creations of the wizard of Menlo Park. His Captain Delgetty, who held his sword and right arm for hire in the market, for any cause or prince who wanted him and could furnish him with rations, has with all his ceremonious pomp and pageantry retired into the background, and the captains of to-day are the captains of industry, who, with the swords of the past, beaten into the pruning hooks of the more peaceful present, stand at the head of industrial armies whose labors are not, as in aforetime, directed to the upbuilding of Chinese walls between countries, and to the obstruction or obliteration of the paths that trade and commerce had opened up between nations.

It is the province of the industrial armies of this better period in the world's history, under the direction of the engineer and inventor of this wiser age, to advance, at a rate never before known, those arts, industries, and inventions that have had for their aim the bringing together in closer bonds of interest, companionship, and good feeling the men of all climes. To recount how this has been brought about the inventions pertaining to the steam engine alone, as illustrated in the locomotive, the huge monsters that animate the floating palaces whose swiftly revolving wheels lash into whitened foam the waters of every known sea, or that rotate the wheels from which thousands of swift-flying spindles catch that hum of industry which brings music to many a home; engines, whose pulsating strokes lift from the lakes and rivers fountains of water for the health and comfort of the citizen, or which, with strange complexity of mechanisms, twist and wrench with a relentless force from out of the hidden recesses of nature, that unseen etheric force which, sent along trellised structures, blossom here and there into arch-lights of dazzling brilliancy, or in remoter recesses, glow in milder incandescence. To the thinking reader will come the thought that if in one single line of industry so much may be said, then to cover all the lines to which engineers and artisans have bent their energies would be a colossal task, too great to be hastily undertaken. It is, however, well to thus review, even ever so briefly, what has been accomplished by the men who, while not recognized in the past as they should have been, are now becoming more prominent in the esteem of all.

Foremost as a worker in a field of industry, the progress of which, in the past fifty years, has been marvelous to a degree, and which, as a factor for good, has no rival, the manufacture of iron and steel, few men, now living, have had a longer or larger experience than has had John Fritz.

Like many another who in this land have earned their promotion in industrial affairs, and have secured the esteem of their fellow-men, he was born of humble parentage and grew up under conditions which, while they debarred him from obtaining that technical training now so readily to be had, taught him that sturdy honesty, persevering fidelity, and untiring industry by which he has been able to accomplish so much within the period of his active life.

Mr. Fritz was born on August 21st, 1822, in Londonderry Township, Chester County, Pa. He was the oldest of a family that consisted of three brothers and four sisters. His parents lived on a farm and the first sixteen years of his life were spent on that farm. At this early age, influenced by a desire to help himself and his parents, and with a wish to know more of mechanical pursuits, he left home and went to Parksburgh near by to work in a country machine shop, with a view of learning the trade of a machinist. As in all the country shops of that day, the apprentice boy had a varied experience which ranged from cleaning castings and striking in the blacksmith shop, up to the more important position of running a drill-press and managing a hand lathe.

While the young men of the present might be inclined to look upon such labor as time wasted, it proved, in this instance, a mine of information and experience, from which, in after years, Mr. Fritz drew much that aided him in the accomplishment of his life work. From there he went to Norristown, Pa., where there were larger shops and larger opportunities. As an illustration of what were the limitations of even the largest shops of that early day, it was said that in this whole establishment there were only one man and a boy who could properly set the valves of a steam engine. From there he was sent to Safe Harbor, Pa., to put up the machinery of a rolling mill under the direction of the manager, the late John Griffin, whom together with David Reeves, Mr. Fritz numbered among his warmest life long friends, and to whom he was very much indebted for counsel and advice.

As an example of the state of the art of planning and building rolling mills and their machinery when Mr. Fritz was a young man, it is said that at one time he happened to be present when a new rolling mill was about to be started, and which was supposed to be very much in advance of any previously built. When all was ready and steam was turned on the engine, to the surprise of the mill men the rolls began turning in the opposite direction to that intended, and when the owner discovered the error, with uplifted hands and a despairing look he came to where Mr. Fritz was standing, and exclaimed: "The whole business is wrong; the mill will have to be built over and turned around." "Oh! no," Mr. Fritz said, in his quiet way; "just turn the cams on the engine shaft half-way around, and the rolls will go all right."

About this time Mr. Fritz was induced to take charge of the Kunsie (anthracite) blast furnace, and after remodeling it and putting it in order, ran it for some time, returning later on to Norristown, from where, in 1854, he went to Johnstown, to remodel and rebuild what has since been known as the Cambria Iron Works. The story of his connection with that pioneer iron and steel plant was so well told by Mr. Fritz at the recent Bridgeport meeting of the American Institute of Mining Engineers, of which society he now is president, that it is quite unnecessary to allude to it here, except to say that no better lesson has been taught or example shown to young engineers and artisans of the value of untiring industry and persistence in following one's convictions when carefully thought out than was the story there related.

In 1860 several gentlemen, some of whom are not now living, organized a company for the purpose of building a furnace and rolling mill on the banks of the Lehigh River, below the then town of Bethlehem, and the young engineer who had done so much for Cambria, and had invented and shown the great advantage of the three-high roll train over the old method, was selected to plan and build what has since acquired a world-wide reputation as the Bethlehem Iron Works. The steady growth and success of this plant, and its enlargement to what it now is, comes so close within the knowledge of every one interested in the current events of the day, as they pertain to the manufacture of iron and steel in all their various forms, that it does not require an extended notice here.

It was in the early days of the Bethlehem Iron Works that rumors of the newly-discovered process of making steel by blowing air through melted cast iron reached the United States, and, outside of the few persons engaged in the experimental plant at Troy, in New York, there were none who were more interested in the study of the process than John Fritz. When, after long delays and numerous disappointments, the experiments conducted under the supervision of the late Alexander L. Holley had achieved sufficient success to induce the investment of capital to build works on a larger seale, the managers of the Cambria Works made arrangements with Mr. Holley to erect at Johnstown a Bessemer steel plant, to be run in connection with their blast furnaces and rolling mill.

At that period George Fritz, a younger brother, had for some time been employed under the direction of John Fritz in the construction and operating of the iron mills at Bethlehem, and Mr. Holley, knowing something of his ability, and knowing, too, of the excellent training that he had gone through, induced him to go with him and assist in the erection and management of the Cambria Company's plant, where, up to the time of his death, he made a record second to none. Soon after this the Bethlehem Iron Company determined also to go into the manufacture of steel under the Bessemer patent, with what success is known far and wide.

The history of Mr. Fritz's life at this period would be incomplete were not some mention made of the coterie of young men who circled about and looked up to him for aid and counsel, and all of whom were active in assisting to develop in the United States this new and as yet incomplete process, and which, later on, was to work such wonderful changes, not only in the United States, but the world over. This group of eight or ten persons might well have been designated as the "Bessemer boys" of '65 and '70. Young, active, and daring, they pushed forward inventions, plans, and appliances which, in other countries and among more conservative people, would have been deemed hazardous, but which, happily, in most instances proved successful, and which did much to advance with rapid strides the production of both iron and steel in the United States.

But the ranks of the "Bessemer boys" have been thinned by death. First to go was the prized leader, Alexander L. Holley. Then followed the "daring engineer, alway advancing, ever right, warm, uncompromising friend, George Fritz;" then the two Jones, Daniel N. and William H. Others remain to meet now and then as captains of industry, to talk over the battles fought and victories won, and, let us hope, to receive the honors and emoluments which they so richly deserve.

Long as is this sketch of Mr. Fritz, it would not be complete were not mention made of the splendid ovation tendered him on the anniversary of his seventieth birthday, when some three hundred of his friends, embracing representatives of the government, noted presidents and professors of colleges, famous engineers, and iron and steel makers from all parts of the country, lawyers, clergymen, and old neighbors met in the floored-over and tastefully-decorated Opera House of Bethlehem to honor him for what he had accomplished as an engineer and to love and respect him for a life which, busy to a degree, had time in which to be courteous to the most lowly, and to give aid, comfort, and sympathy to the unfortunate and poor.

The regard in which Mr. Fritz is held is by no means confined to his own country, for beyond the sea his record is known, his skill acknowledged, and his character admired. But a few weeks ago the president of the British Iron and Steel Institute, E. Windsor Richards, came to the United States mainly that he might place in the hands of his warm personal friend the token of his society, which, when awarded to any one, is their highest recognition of the engineering skill and honorable and manly character of its recipient, and when John Fritz reached out his hand to receive the Bessemer gold medal, sent him from over the sea, his modesty made him say: "I receive it not so much for what I have done, but for what American engineers and workmen have, by my help, accomplished."

NOTES ON CEMENT TESTING.

BY H. M. NORRIS.

Cement, in some form, has been used since the darkest of prehistoric times, and, in an engineering sense, means such a combination of lime, silica, alumina, and iron, that when properly calcined, reduced to powder, and gauged with a proper amount of water, it has the property of setting, both in water and when exposed to the action of air.

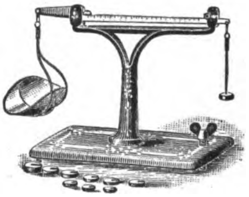
Natural cement is made from an impure limestone, in which nature has mixed such proportions of lime, silica, and alumina, that when the carbonic acid is expelled, the lime is in the proper proportions to make a hard compound with the silica and alumina. This stone is found in various parts of the world, and owing to the comparatively low cost of converting it into cement, has always been a most important factor in the materials of construction. Very little advance, however, was made in cement working until 1824, when a patent was granted to John Aspdin, of Leeds, for the manufacture of Portland Cement.

Portland Cement is an artificial production made by mixing certain known proportions of clay and chalk, containing silica, alumina, iron, and carbonate of lime, burning this mixture to the point of incipient vitrification, and then reducing the mass to an impalpable powder.

In order to ascertain the quality and characteristics of this powder, it is necessary to be familiar with the maximum results that may be obtained with any given type of cement. This fact makes it of the utmost importance that engineers should have a thorough understanding of the best and most rapid methods of testing cements. No great equipment of scientific education is necessary for this, but to be of any comparative value, all tests should be made under one system. From the engineers' and consumers' view it makes very little difference what that system is, provided all use the same, for what is fair for one is fair for all. A uniform system, besides being reasonably accurate, must be simple, rapid, and easy of application.

Sampling.—Where cement has a good reputation, and is used in large masses, it is usually sufficient if every fifth barrel be tested, but in very important work, such as the thin walls of sewers, it is often necessary to test every barrel; the samples being selected from the interior of the barrel, and at a sufficient depth to insure a fair exponent of its quality. These samples should be placed in some tightly-closed receptacle, impervious to light or dampness, until required for manipulation.

Fineness.—The strength of a cement depends largely upon the fineness to which it is ground, for the finer it is the more grains of sand it will cover, and the better it will fill the interstices of the stone. Fineness, alone, however, is no sure indication of its value, as there are some cements so low that no amount of pulverizing will redeem them. In tests for fineness three sieves are used; No. 50 sieve, 2,500 meshes to the square inch, made of No. 35 wire, Stubb's wire gauge; No. 74 sieve, 5,476 meshes to the square inch, made of No. 37 wire, and No. 100 sieve, 10,000 meshes to the square inch, made of No. 40 wire. A weighed amount of cement is taken and sieved with the No. 50 sieve. What passes through is carefully weighed, and its percentage of the original amount calculated. A similar amount of cement is taken and tested on the No. 80 sieve, and similarly on the No. 100 sieve, the percentage passing through being calculated. These measurements are made on a small scale weighing to .0001 of a pound. For comparative tests, briquettes should be made with cement that has passed through a No. 100 sieve, but for a particular piece of work the cement should be used as it comes in the barrel.

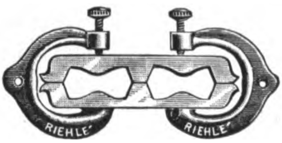


Sand.—When tests are made to determine the value of a cement for any particular piece of work, the sand used should be the same as is to be used in the work, but for comparative tests, it is necessary to use a standard sand that can readily be duplicated. For this purpose, crushed quartz is used, the degree of fineness being such as to pass a No. 20 sieve, and caught on a No. 30 sieve.

Mixing.—The mixing of the mortar for testing should be done upon glass, porcelain, slate, or other non-absorbent surface. It must be done thoroughly, rapidly, and in a constant temperature between 60° and 70° Fahrenheit. For natural cements, use one part cement and one part sand; and for Portland Cements, one part cement and three parts sand. These proportions are by weight. Mix thoroughly, and then add sufficient water to give the mass the consistency of damp sand. To obtain good results, as little water should be used as possible, the actual amount depending upon the quality of both the sand and cement, and also the proportions in which they are used. There is little danger of using too little water, only 20 to 25 per cent. being required for neat cement, 15 per cent. for one part of sand, and 10 to 12 per cent. for three parts of sand. These percentages are in proportion to the combined weight of the cement and sand. In preparing a quantity of cement for neat or sand briquettes, this mixture should be thoroughly kneaded by hand, using rubber gloves as a protection, and afterward troweled until perfectly homogeneous. For neat tests, the cement should be worked until it sheds water, and with sand until all the grains are covered.

Molding.—When the sand and cement are thoroughly incorporated, the mortar is pressed into oiled molds with sufficient pressure to exclude all air bubbles and make the briquettes compact and uniform. After filling, the molds should be smoothed off on both sides with a spatula or trowel, and laid away under a damp cloth for twenty-four hours, when the briquettes should be removed from the molds and immersed in water of 65° to 70° Fahrenheit, care being taken that they are completely submerged.

In making briquettes by hand, it is usual to mix only sufficient mortar to make five tests. With a larger quantity there is danger of an incipient set, and the necessity of reworking the mortar. The evils attending this operation are well understood, and it is for this reason that several machines have been designed by the use of which briquettes are not only made much faster, but insure a much greater uniformity, the variation being reduced to about two per cent.



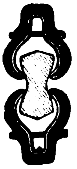
To make five briquettes of standard size of the neat cements requires about one and two-thirds pounds of material; and for those containing one part of cement to three of sand, about six and two-thirds ounces of cement and one and one quarter pounds of sand.

Setting Test.—The rapidity with which a cement loses its plasticity shows its initial hydraulic activity. Cements that set in less than half an hour are termed quick-setting, and those requiring a longer period slow-setting. Quick-setting cements should not be worked longer than a minute, or slow-setting longer than three minutes. As soon as the cement has assumed sufficient hardness to bear the gentle pressure of the finger-nail, it is considered as beginning to set. The time of setting is usually measured by the penetration of a steel point, termed "The Needle Test." This test was first used in this country by Gen. Q. A. Gilmore, and consists of a one-twelfth inch wire, loaded with one-fourth pound, and a one-twenty-fourth inch wire loaded with one pound. Pats are made of neat cement about two and one-half inches in diameter, one-half inch thick in the centre, and one-fourth inch thick at the edges. For the initial set, the time is recorded from when they are made to the time when they will support the one-fourth pound weight without making an impression, and the final set until they will support the one pound weight. If the pats will not bear the one-fourth pound weight after five hours, the cement should be rejected.

Checking Test.—The test for checking or cracking is an important one. Make two pats of neat cement same as for the setting test, and note the time it takes to set hard enough to bear the one-fourth pound and one pound loads. When hard enough, one of these cakes should be placed in water and examined from day to day to see if there are any indications of contortions or cracks. The other pat should be kept in the air and its color observed, which for a good cement should be free from blotches.

Boiling Test.—Make a briquette or thin cake of neat cement as above, allow it to set hard in the air with a damp cloth over it for twenty-four hours, then immerse in boiling water and boil for twenty-four hours. This boiling causes the coarse grains to disintegrate; and if there is an excess of free lime in the cement, the caustic lime, becoming hydrated, swells and causes the cake to crack. This cracking and disintegrating is called "blowing," and any cement acting this way should be rejected. Care must be taken, however, not to confuse the fine hair-lines found on the surface which cross and recross each other, with the coarser, wedge-shape cracks due to swelling or blowing, for the fine lines are merely the result of slight changes in temperature, and do not denote a poor cement. This test should be used in conjunction with the sand test and test for fineness to determine accurately the quality of the cement.

Tension Test.—The test for tensile strength is the most common of all tests, though not a perfect indication of the value of a cement. It is frequently the only test used in comparisons of different kinds, but the results obtained from neat cements do not give uniform conclusions regarding the binding properties of the cement and sand. In comparing several varieties of cement, it is necessary to use a high percentage of sand, as the setting properties of different varieties vary much with the amount of sand. A proportion (by weight) of one part cement to three of sand is taken as the standard for Portland Cements, and equal parts of sand and cement for natural cements.

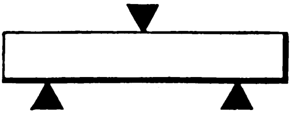


After the briquette has attained the requisite age, it is placed in the testing machine and subjected to a strain of 400 pounds per minute until fractured. In adjusting the clips to the specimen the greatest care must be exercised that everything comes to a full and even bearing, as carelessness in this respect leads to a greater variation in results than from any other cause. Briquettes for tensile tests are left one day in air and one day in water, *or* one day in air and six days in water, *or* one day in air and twenty-seven days in water. These three are the usual tests, though the briquettes are sometimes allowed to remain in water as long as a year.

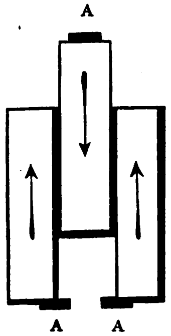
Compression Test.—The test for compressive strength is a most important one and should never be omitted, for in practice mortar is chiefly called upon to withstand pressure. After a cement is allowed to harden for a few years, it ceases to grow in tensile strength, but its resistance to crushing continues to increase until it becomes like a piece of pottery.

Compressive test specimens, in order to give results that agree with each other, should be made by machinery, either by grinding down the regular form of machine-molded briquettes into one-inch cubes or by molding them direct in a machine designed for that purpose.

Bending Test.—The methods of testing cements by flexure possesses some very marked advantages over the more common practice of testing by longitudinal straining. In tensile tests it is a very difficult matter to adjust the briquette in the clip so that there will be no twist or cross strain, but in the transverse method there can be no such ambiguity as to strain, as the specimen rests free and clear upon two supports, and is broken by the load applied in the centre, giving a very great gain in the per cent. of good breaks. Parallelopipedons one inch square by six inches long placed upon clips with four-inch span give very satisfactory results.

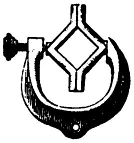


Shearing Test.—By this test many important facts may be gathered on the shearing strength of mortars. For Portland Cements, mix one part, by weight, of cement to three of sand, and for natural cements, one part cement to one part sand, as usual. Soak three bricks in water for two hours and then lay the joints as shown in the sketch. After twenty-eight days, in a constant temperature from 65° to 70° Fahrenheit, place three one-quarter inches by one and one-half inches soft white pine blocks at A, A, A, and apply power in the direction indicated by the arrows. This gives a result as nearly as possible like shearing, the pressure being concentrated along the mortar joints.



The adhesion of Portland mortars to pressed brick is greater than to common brick, but the difference is not as marked as in natural mortars. And further tests of Portland mortars made under water are stronger than open-air ones while with natural mortars the reverse is the case. The results are independent of the thickness of the joints.

Abrasive Test.—Cement that is to be used for sidewalks, floors, artificial stone paving blocks, and the like, should be subjected to this test. And not only should the neat cement be tested, but also the mixture of cement and sand that is to be used in the actual work.



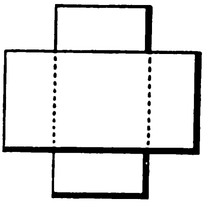
To prepare a specimen for the abrasive test, make an inch cube of the neat cement or cement and sand, and allow it to harden under water for not less than seven days. Upon removal, dry thoroughly and remove all loose particles with a stiff brush, then weigh and place in the Testing Machine.

This machine consists of a revolving hardened steel disk, upon which the specimen is automatically moved slowly back and forth. Above the disk is a weighted lever or graduated beam capable of loading the specimen up to two hundred pounds. The bracket supporting this beam is fitted with a sand box and water cock, each of which is provided with means of regulating the supply, giving more or less sand or water as the nature of the test demands. The apparatus is provided with a revolution counter which automatically registers the revolutions of the disk.

After the specimen is subjected to this rubbing action for a given time or registered number of revolutions it is removed, again weighed, and the loss carefully noted. The loss of weight of an air specimen is greater than that of a water specimen and the loss of a neat cement greater than that of mortar.

Absorption Test.—This test is used to determine the relative density of briquettes, the common practice being to use an end of a fractured specimen. This, after being thoroughly dried, is placed in an oven of 100 degrees Centigrade for two hours. It is then weighed and immersed in distilled water for twenty-four hours when it is removed, again weighed, and the gain in weight carefully noted; the percentage being computed in terms of the original weight.

Adhesion Test.—In the test for adhesion the best comparative results can be obtained by connecting together two thick, coarsely-ground pieces of glass, and allowing them to harden under a damp cloth for twenty-four hours before immersion; then pulling at the end of twenty-eight days. But if the tests are made for a particular piece of work, the same material should be used in the tests that is to be used in the work, care being taken that the brick or stone be wet in exactly the same manner as for the work itself.



Cohesion Test.—This test is the same as for tensile strength, and is recommended by most of the engineering societies, but, taken alone, it is of far less practical value than some others already cited.

Expansion and Contraction Test.—Stability of form is a feature that all good cements should possess, for after the process of setting has once commenced, it is necessary, for the future durability of the work, that the cement should neither swell nor shrink.

For accurate comparative tests, Bauschinger's caliper apparatus is used. With this instrument expansion or contraction can be measured with an accuracy of .005 of an inch. But where approximate results only are sought, the cement may be pressed into a glass tube or lamp chimney, and after setting, the shrinkage determined by the amount of water that will run down the inside; any undue amount of expansion showing by the breaking of the glass.

Sugar Test.—It has been stated that the use of sugar in lime, as practiced in India, was beneficial, and that one-half to one per cent., by weight, of sugar would, in from four to six months, show a considerable gain in strength. Recent experiments, however, tend to disprove this theory, and go to show that sugar has the opposite effect, and weakens cements.

THE DEFLECTION OF BEAMS UNDER IMPACT.

The laws of the deflection of beams under static loads, in cases where the elastic limit is not exceeded, are well known. If, however, a load falls upon a beam the deflection is much greater, as this is a case of impact. The formulas for impact have as yet scarcely found their way into text-books, although discussions are given in the last (sixth) edition of Merriman's *Mechanics of Materials.* From this work the following formula for the deflection of a beam under the action of a falling weight is taken.

Let P be the weight of the load which falls through the vertical height h upon the middle of a beam supported at its ends. Let d be the static deflection due to P, which can be either directly measured or be computed by the common methods. Let D be the actual dynamic deflection due to the impact of the falling load. Let W be the weight of the beam. Then the dynamic deflection is

$$D = d + \sqrt{2mhd + d^2}$$

in which m is a number depending upon the ratio of P to W and whose value is given by

$$m = \frac{35P}{35P + 17W}.$$

From this formula the deflection of the impact of a falling load can be ascertained, provided that the stresses in the beam do not exceed the elastic limit of the material.

As a verification of the formula, an experiment given by P. H. Dudley, in the *Railroad Gazette,* of May 31st, 1895, may be quoted. A railroad rail, thirty feet long and weighing eighty pounds per yard, was placed with its ends upon rigid supports. A load of 100 pounds gradually applied gave a static deflection of 0.12 inches, but the same load, dropped from a height of one foot, gave a maximum deflection of 0.91 inches. Here $P = 100$ pounds, $h = 12$ inches, $d = 0.12$ inches, and $W = 800$ pounds. The value of m is now found to be 0.2047, and then from the formula the dynamic deflection $D = 0.897$ inches which closely agrees with the observed value of 0.91 inches.

If h = o in the above formula, then D = 2 d, or the dynamic deflection is double the static deflection. This is the case of a load suddenly applied where its full intensity acts during the entire period of the deflection. The formula thus also shows what has long been known, that the deflection and stress due to a sudden load is double that of the same load when gradually applied. This conclusion, however, like the formula itself, is only true when all the stresses are less that the elastic limit.

TESTS OF CAST-IRON CAR WHEELS.

An interesting series of tests of chilled cast-iron car wheels was made November 9th at the shops of the New York Car Wheel Works and Griffin Machine Works, at Buffalo, N. Y. The tests were made under foreign specifications for tests of steel wheels and the Master Car Builders' Association standard specifications for tests of cast-iron wheels, and all the wheels more than fulfilled the requirements. The general results of the tests are given in tabular form, and the following notes explain the conditions more fully:

Test No. 1.—Made on a standard double-plate wheel, under the Austrian State Railway specifications, by which the wheel must be placed upright on a heavy iron and stone foundation, and must stand eight blows from a weight of 475 pounds, dropped from varying heights, commencing at 3.28 feet and increasing by 1.64 feet to 19.68 feet, the test continuing until the wheel fails. This wheel stood nineteen blows, nine of which were from the full height, the wheel then breaking in two pieces. Slight cracks first appeared at the seventh blow, and gradually extended.

Test No. 2.—Made under the Hungarian State Railway specifications, which are similar to the above. The wheel stood seventeen blows, seven of which were from the full height. Slight cracks first appeared at the eighth blow.

Test No. 3.—Made on a 30-inch spoke wheel for engine truck, Lake Shore & Michigan Southern Railway, under the Austrian State Railway specifications for test. The first fine cracks appeared at the sixth blow, and extended until, at the twelfth blow, the wheel broke.

Test No. 4.—Made on a 39-inch wheel, under the German State Railway specifications for test, by which the wheel must be placed horizontally on wooden blocks and have a tapering steel wedge placed in the centre. The wheel must stand six blows of a weight of 440 pounds falling from varying heights, commencing at 4.92 feet and increasing by 1.64 feet to 13.12 feet. Small cracks appeared at the twelfth blow, and extended until, at the seventeenth blow, the wheel broke.

Test No. 5.—Made on a 42-inch wheel, under the French State Railway specifications for test, by which the wheel must be placed upright on a heavy iron and stone foundation, and stand three blows of a weight of 2,200 pounds falling 14.76 feet, the test being continued until the wheel breaks. This wheel stood six blows without breaking, when the test was discontinued on account of the difficulty of handling the weight.

Test No. 6.—Made on a double-plate passenger wheel, under the M. C. B. specifications for test, by which the wheel must be placed horizontally on a heavy iron and stone foundation, and must stand five blows of a weight of 140 pounds falling 12 feet, the test being continued until the wheel fails. A small crack in the plate appeared at the thirty-eighth blow, and there was a gradual development of cracks through tread and plates, the wheel breaking in two at the fifty-sixth blow.

Test No. 7.—Made under the M. C. B. specifications for test. A crack in the plate appeared at the forty-fourth blow, no further effect appearing until a crack appeared in the tread at the one hundred and ninetieth blow, when the cracks gradually extended until, at the two hundred and sixty-third blow, the wheel broke.

Test No. 8.—Made under the M. C. B. specifications for test. A small crack appeared in the plate at the twenty-third blow, no further effect appearing until the forty-fifth blow developed a crack through the tread. The wheel broke at the sixty-third blow.—*Engineering News.*

No.	Wheel.		Drop Weight, pounds.	Height of drop, feet.	Number of blow producing first crack.	Number of blows before breaking.	Remarks.
	Diameter, inches.	Weight, pounds.					
1	38	800	475	3.28 to 19.68	7	19	Broke in 2 pieces.
2	38½	840	475	3.28 to 19.68	9	17	" "
3	30*	950	475	3 28 to 19.68	7	12	. . . .
4	39	840	440	4 92 to 13.12	12	17	. . . .
5	42	1,075	2,200	14.76	. .	6	Not broken.
6	36	750	140	12	38	56	Broke in two.
7	42	1,075	140	12	44	263	. . . .
8	33	600	140	12	23	63	. . . .

* Spoke.

RECENT EXPERIMENTS WITH HEAT TESTS FOR CEMENT.

The value of accelerated tests—generally heat tests—of hydraulic cements to determine their durability has been much discussed in recent years. In our issue of August 24th, 1893, we reviewed at some length the various accelerated tests practiced, and outlined briefly such conclusions as the evidence at that time seemed to warrant. The question is an important one to cement users and manufacturers. The durability of a cement is, of course, a far more important factor than its strength within reasonable limits, for it matters little how great a strength a cement may develop, if in a few months or years it will disintegrate and fall to pieces. Any method of testing, therefore, which will enable an engineer to know beforehand what durability may be expected of a cement is of great value.

Heat tests have shown much promise in this respect, although they have been little adopted, and, indeed, have been vigorously opposed by many very competent engineers. They are, however, we believe, gaining more and more the attention of cement users, both in this country and abroad. In the report of the French Commission on uniform methods of testing materials of construction,* recently issued, the subject is discussed briefly by Mr. H. Le Chatelier, who takes the extensive experiments of Prof. L. Tetmajer, of Zurich, as the basis for his remarks. The following is an abstract of Mr. Le Chatelier's Discussion :

"In the course of time all hydraulic cements and limes employed in works of construction are disintegrated by the various influences of nature. The longer a cement resists these attacks the better it is. It would seem important, therefore, to be able to ascertain by tests the degree of this resistance. The causes of disintegration are many, but may be divided into two classes: (1) Those which act only under certain conditions, as the action of sea water, frost, heat of the sun, etc., and (2) those which act under all conditions, as water and carbonic acid. The action of these last are less energetic than that of sea water, frost, etc., and are dangerous according to the continuity of their action. These two last agents, water and carbonic acid, have an important influence upon the initial hardening of cement, but act in the long run to bring about the destruction of certain cements, but only those which are inherently defective in quality.

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*Commission des Methodes d'Essai des Materiaux de Construction. Tome IV: Section B, Materiaux d'Aggregation des Maconneries. J. Rothschild, Editeur, Rue des Saints-Peres, Paris.

"The test of durability or invariability of volume has for its object the determination of the resistance of cements to these various destructive influences or agents of nature. In these tests the cement is generally molded in good sized pats or cakes, with thin edges. This formation of the pats renders the deformations which occur more easily observed. The alterations are manifested by total disintegration or more often by cracks, scaling, etc. Often these phenomena require a long time, months or years, for their full development. For practical purposes it is necessary that the phenomena be developed much quicker.

"Mr. Tetmajer proposes to employ heat to bring about this quicker action, since in all chemical reactions the action of heat accelerates the process. Five methods of heat tests have been compared by Mr. Tetmajer. In all cases the hydraulic cements or limes were gaged in the forms of pats, and placed during setting in a moist atmosphere. The pats were subjected to tests at the end of twenty-four hours if they had set before that age, otherwise immediately after setting.

"I would point out here two grave defects in this mode of operation. The settling of the water, inevitable in briquettes hardening in air, causes a very great difference between the upper and lower parts. This effect is more marked as the rate of setting is lower. The uniform preservation of all pats for twenty-four hours, some of which set in a few minutes, others at different ages up to twenty-four hours, establishes an inequality of conditions. The resistance at the moment of immersion and the action of the hot water are very variable in the different tests.

"The tests were as follows:

"(1) Tests in cold water.—Pats varying from 1 cm. thickness at the centre to nothing at the edges, and 1 dm. in diameter preserved for three years.

"(2) Tests in Air.—Pats like those for the cold water tests preserved in a moderately moist atmosphere under a uniform temperature for three years.

"(3) Kiln Tests.—Pats of the form before described placed on supports in a vessel having several millimeters of water in the bottom. Heat was applied gradually, so that the water was evaporated in from three to six hours. So long as the water was evaporated the temperature was about 95° C. After evaporation the heat was continued one-half hour until the temperature was 120° C. Under these conditions the interior of the pats did not rise to a higher temperature than 100° C.

"I would remark that this manner of operation cannot be easily made comparable with itself, as it is impossible to apply the heat at exactly the same rate in every test. Moreover, after the evaporation of the water the temperature near the bottom of the vessel is greater than near the top.

"(4) Red Heat Tests.—A ball several centimeters in diameter placed upon a frame and subjected to a gas flame. The heat was regulated so that at the end of the first half-hour the temperature of the ball was that of the hand, and after the second half-hour 90° C., and then at the same rate until the ball was red-hot.

"It is hardly necessary to say that this test is less easily regulated than the kiln test.

"(5) Cooking or Boiling Test.—The ball placed in a vessel of water over the fire, and the water brought to the boiling point in one and one-half hours and kept boiling for six hours.

"This is the only heat test proposed by Mr. Tetmajer in which it is possible to secure the same conditions in all cases.

"The experiments were made with Portland cements, slag cements, natural cements, and hydraulic limes, and the results were as follows:

"*Portland Cements* —Of 139 cements tested, two only showed signs of disintegration after three years in cold water. In the tests in air, 18 altered completely and seven showed less marked disintegration. The boiling or cooking tests destroyed 17 cements completely, and developed cracks in 11 more. All the cements disintegrating in air were destroyed by the boiling test, but while the disintegration in air became evident only after a year, it was developed by boiling in six hours. A certain agreement appears to exist between the time necessary to develop disintegration in air and in boiling water. The cements which disintegrated in air in less than six months could not resist the boiling water more than four hours, and those which stood in air only a few days disintegrated in boiling water in less than two hours. The results obtained do not permit of any definite relations being deducted on this point. The kiln tests and red heat tests give results identical with the boiling tests. In conclusion, it may be said that the results of the tests on Portland cement demonstrate that for such cements the boiling test is excellent. It gives in six hours the same results that a test of a year's duration in air does.

"*Slag Cements.*—All 46 cements tested showed no change in cold water. In air five were much disintegrated and 15 less markedly so. The results of the tests in air vary between themselves according to the degree of humidity. The boiling test gave no case of absolute disintegration, but five cements developed cracks, all five being those which had failed in air. The kiln and red heat tests gave less marked results than the boiling test. In conclusion, it may be said that the boiling test is still of interest, but not so good a proof as for Portland cements. It disintegrated the slag cements which were certainly bad, but not those which were doubtful.

"*Natural Cements.*—Both quick and slow-setting cements were tested, 45 cements in all. All proved sound in cold water and in air. In the boiling test 13 were destroyed completely and eight were cracked. The kiln and red heat tests showed less marked results. Mr. Tetmajer concludes that neither of the three heat tests is suited to natural cements, and proposes a hot water test of 50° C. With this test none of the cements would fail. I consider the results too peculiar to be accepted without verification. Natural cements are always more irregular and less to be calculated upon in their action than artificial cements. It is difficult to believe that out of 45 cements selected at hazard none was bad. Moreover, several of the cements were natural Portland cements, presenting all the characteristics of veritable Portland cements, and it is not easy to understand how a test excellent for the one should be directly the contrary for the other.

"*Hydraulic Limes.*—Of the 104 limes tested 10 per cent. showed more or less pronounced disintegration in cold water and air. In boiling water 30 disintegrated completely and 20 cracked. In the kiln and red heat tests the failures were as numerous, but less pronounced than in the boiling test. Mr. Tetmajer concludes that these heat tests are not suitable to hydraulic limes, and proposes, as for natural cements, the hot water test at 50° C. I do not consider this conclusion absolutely justifiable. The failure in boiling water of limes which stood in cold water was always with slow-setting limes. They were surely immersed before true set had taken place.

"It appears from these tests that the use of the hot water gives a really accelerated test, since it is ended in six hours. No hydraulic lime or cement notoriously bad can escape the boiling test. It remains to prove that all cements unable to stand the test are really bad."—*Engineering News.*

A number of experiments were recently made to ascertain the length of time that brick and sandstone are rendered waterproof or protected by oil. The three oils used were linseed oil, boiled linseed, and crude mineral oil. The amount of oil and water taken up by the sandstone was very much less than that absorbed by the brick, although the area of the sandstone cube was much greater. Equal amounts of the raw and boiled oil were absorbed. The mineral oil, however, was taken up in much greater quantities by both brick and sandstone. By the end of twelve months the mineral oil evaporated from the bricks, but such was not the case when the other oils were used. After an exposure of four years the bricks practically retained all their oil, inasmuch as they had not lost any of their weight, and were also nearly impervious to moisture. It was noticeable that the sandstone cubes treated with linseed oil returned to their original weights, but do not appear to have lost the beneficial effect of the oils, being also practically waterproof.—*Mining and Scientific Press.*

Tests of Swedish cast iron are interesting as showing the strength which can be obtained in that metal. A concern in Sweden has been trying to produce an extra strong cast iron, the leading motive being a desire to reduce the thickness of shrapnel shells so that the capacity of the chamber within them can be increased. Tests of a recent series of castings gave an average tensile strength of 19.5 long tons per square inch, with .38 per cent. extension in 4 in. The concern making the castings guarantees a strength of 17.8 long tons per square inch.

CLOTH AND CANVAS SPECIFICATIONS ADOPTED BY THE UNITED STATES WAR DEPARTMENT.

There has been considerable confusion among cloth and canvas manufacturers in regard to the strength of such materials as used by the United States War Department, the trouble being due to the various widths of grips and lengths in which the tests were made, and arising from the seeming lack of knowledge of the following specifications adopted by that department.

CLOTH AND CANVAS SPECIFICATIONS UNITED STATES WAR DEPARTMENT.

NAME.	DESCRIPTION.	WIDTH	THREADS.		WEIGHT PER YARD IN OZS.	STRENGTH PER 1 IN. OF WIDTH.		ADOPTED.
			WARP.	FILL.		WARP.	FILL.	
		Inches.						
Dark-blue cloth, ...	Pure long staple American fleece wool, mixed in equal proportions of three-quarters and full blood, ...	54	66	60	20	50	42	2–20–'91
Blouse lining flannel, ...	Warp of No. 40 long staple American cotton yarn, filling of one-quarter blood American fleece wool, mixed with long staple American cotton of 75 parts wool to 25 parts cotton, ...	27	56	48	6	40	38	4–2–'87
Dark blue Kersey, ...	Three-quarter blood bred wool, . . .	54	76	68	22	58	50	8–19–'90
Dark-blue, cloth finished blouse flannel, ...	Pure long staple American fleece wool, mixed in equal proportions of one-half and three-quarter full blood, ...	54	60	52	13	28	23	3–21–'85
Sky-blue Kersey, heavy quality,	Pure long staple American fleece wool of one-half blood bred, ...	54	50	55	22	65	60	3–3–'92
15-ounce cotton duck, ...	American cotton, not inferior to low middling, ...	28½	44	32	15	300	220	9–26–'90
12-ounce cotton duck, ...	American cotton, not inferior to low middling, ...	28½	44	30	12	256	168	3–12–'79
10-ounce cotton duck, ...	American cotton, not inferior to low middling, ...	28½	46	32	10	216	128	3–12–'79
8-ounce cotton duck, ...	American cotton, not inferior to low middling, ...	28½	50	32	8	156	90	3–12–'79
6½ to 7-ounce cotton duck, .	American cotton, not inferior to low middling, ...	28½	52	48	6½	144	60	3–28–'89

NOTE.—The figures given for strength of cloth or canvas per inch of width refer to tests made with the grips of the testing machine one-half inch apart. The cloth is tested in one-inch widths and the canvas in one-half inch widths.

AN EXPERIMENTAL STUDY OF BELT-LACING.

BY WALTER FLINT, M. E.

Every one who has had the care of belting has always had a decided preference for some particular form of lacing, and no doubt has ever existed in his mind that it was the best.

It is the object of this paper to demonstrate, so far as possible, which of the most common joints is the strongest, *the question of wear not being considered.*

Another point to be determined is the efficiency of the round-punched holes compared with the narrow slit cut with a belt awl. It is claimed by many practical men that holes made with the awl are better, because none of the leather is removed. Good reasons for doubting this theory have appeared, but no actual proof has been presented.

In making these tests 4-inch belting was selected and laced thoroughly with ¼-inch lacing, well stretched. Five holes were punched ¾ inch from the end for a single row of holes, and for a double row of holes the second row was 1½ inches from the end. The punched holes were $\frac{3}{16}$ inch diameter. These five holes removed $\frac{15}{16}$ inch from the width of the belt. The belt being four inches wide, the net section is about 76 per cent. of the solid belt, while in the cases where the holes were cut with an awl the net section is theoretically about the same as the solid belt.

The apparatus for holding the specimens was so constructed that the belt was free to move as though it were on pulleys, thus equalizing the strain in that direction. It was then held in the testing machine by hooks, which allowed it to stretch more on one side than the other if it wanted to. This latter condition is not strictly true of a belt on pulleys, but considering the very short length of the samples it was thought best to have it so.

No. 1 AND 1A.

The form of this joint is plainly shown in cut No. 1, and No. 1*a* shows the break. The belt was not injured. The lace broke in the middle first and then on the edge. The joint failed under a tension of 1,150 pounds.

Since the net section should hold about 2,065 pounds, it is clear that more lacing should be put in.

No. 2.

This is the same form of joint as No. 1, except that the holes were made with an awl. It was not thought worth while to photograph this one before testing. It will be noticed that the lace cut the belt from the holes in various directions. The lace did not fail till after the belt failed on the lower side.

The joint failed at 790 pounds, and the form of the break shows that the failure was due to the form of holes rather than weakness of belt.

No. 3 AND 3A.

Same number of holes and punched same as No. 1, but double laced, as shown in cut No. 3. The break is shown in cut No. 3*a* at *c*. The lace was not broken.

Tension applied, 1,460 pounds.

No. 4.

Exactly the same as No. 2, except that it was double laced as No. 3.

Tension applied, 1,335 pounds.

It failed by the lace cutting through the belt. Shape of holes was cause of failure. The lace was not injured.

These tests would seem to show that holes cut with an awl are far inferior to punched holes.

No. 5 AND 5A.

This was a trial of one of the metallic fastenings. The fastenings being 1 inch long, the holes had to be made ½ inch from the end of belt.

No. 5*a* shows the broken joint.

Tension applied, 725 pounds.

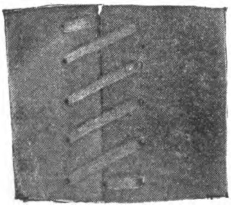
Two of the hooks broke, one straightened out, one pulled through the belt and one remained sound, thus showing failure of both belt and fastenings.

No. 6 AND 6A.

Same as No. 5, except that by staggering the holes four more hooks were put in.

No. 6*a* shows the broken joint which failed under a tension of 1,480 pounds.

Both belt and fastenings failed.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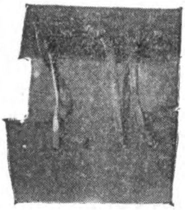
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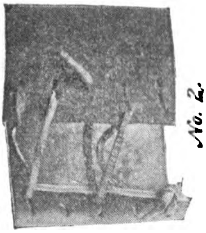
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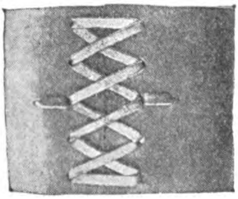
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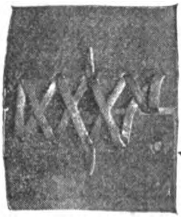
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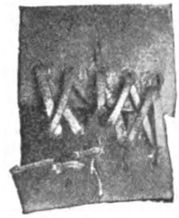
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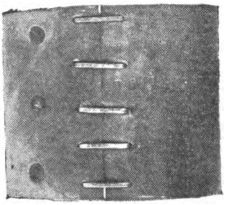
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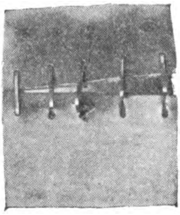
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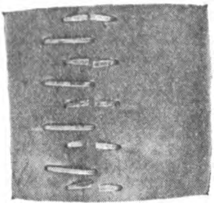
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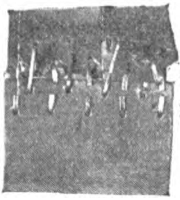
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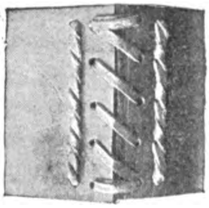
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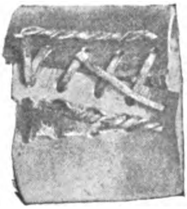
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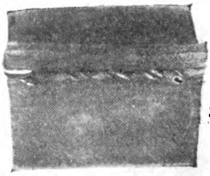
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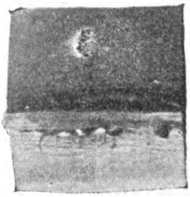
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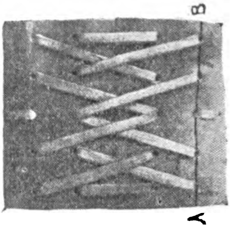
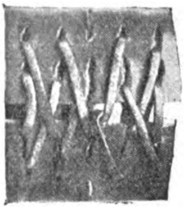


No. 9.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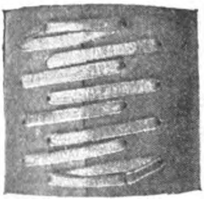
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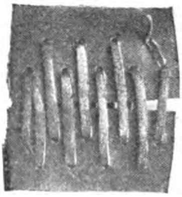

No. 11a.

No. 7 and 7a.

Cut No. 7 shows this form of joint. Holes punched. The break is shown in 7*a*, and took place at 1,510 pounds.

The lace failed in one place, while the belt failed generally.

No. 8 and 8a.

This is known as the "boot leg" lacing, and is a great favorite in eastern Maine, because of its durability. Of course, it cannot be used with a tightener nor in many other places.

No. 8*a* shows the break which occurred in the lace; the belt itself had started to tear in several places on the inside.

Tension applied, 1,310 pounds.

No. 9.

This is a double-laced joint with only one strand in each hole. Holes punched. The negative of the broken specimen was lost, but the break occurred along the line *A B*. The lace was not injured. As near as could be observed the break was simultaneous along *A B*.

Tension applied, 2,015 pounds.

The net section of belt should have held about 2,065 pounds. This would seem to show that nothing further can be obtained when five $\frac{8}{16}$ inch holes are used, since the lace held more than the belt.

No. 10.

Same as No. 9, except that holes were cut with an awl. It was thought since No. 9 failed on account of too small a net section, that by making holes with an awl might possibly help matters. The cut shows the result. The lace was not injured.

Tension applied, 1,590 pounds.

No. 11 and 11a.

No. 11 is peculiar in that the holes are staggered, one strand in each hole, and strands not crossing on either side. There appears to be no reason why it should not hold as much as No. 9. The lace was evidently faulty, since the holes did not appear particularly strained. No. 11*a* shows the broken lace on the lower side.

Tension applied, 1,835 pounds.

This comes the nearest to No. 9 in strength.

—*American Machinist.*

TESTS OF LEATHER BELTING.

BY PROF. CHAS. H. BENJAMIN.

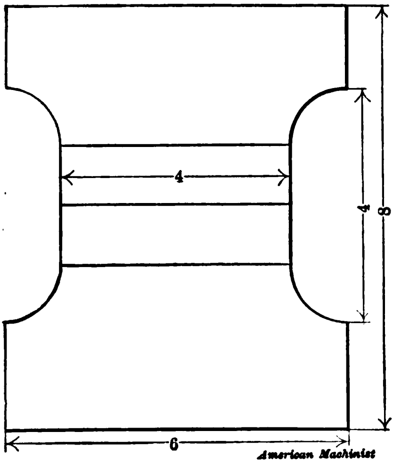
Having noticed the article by Professor Flint, in the *American Machinist* for September 5th, on "A Study of Belt Lacings," it occurred to me that the readers of this paper might be interested in the results of some experiments recently made on the strength and elasticity of the belts themselves. These experiments were made by Mr. E. A. Drake, in the testing laboratory of the Case School of Applied Science, under the direction of the writer.

The object of the experiments was to determine the ultimate tensile strength and percentage of elongation of the best quality of oak-tanned leather belting, as made by different manufacturers, and to observe the relative strength of single and double belts of the same make.

In order to obtain fair samples, the belting was all bought through outside parties in the ordinary course of trade, and the prices and discounts were practically the same for each series.

The samples obtained were the product of three of the leading belting factories of this section, and I simply will denominate them as Series 1, 2, and 3. Each series contained ten linear feet of single belting, and the same length of double belting, all being six inches wide.

The belts were cut into eight-inch lengths, making fifteen test pieces of each kind, and the specimens were then trimmed to the shape shown in Fig. 1 to insure breaking outside the jaws.



American Machinist

Parallel lines one inch apart were ruled across the test specimen by which to measure the elongation from time to time. The specimens were gripped at each end by corrugated interlocking jaws, and the holders containing the jaws were so pivoted in the testing machine as to insure an even pull on the two edges of the belt.

The loads were applied gradually and the elongation measured at each 500 pounds increase of load. The per cent. of elongation in two inches of length for a total load of 2,000 pounds on 500 pounds per inch of width has been placed in the tables.

The average thickness of the single belts was about 0.20 inch, and of the double belts about 0.35 inch.

TABLE I.

SERIES NO.	SINGLE OR DOUBLE.	NUMBER OF SAMPLES.	LOAD IN POUNDS PER SQUARE INCH.	LOAD PER INCH OF WIDTH.	PER CENT. ELONGATION.
1	Single.	13	4,770	905	9.88
1	Double.	15	3,525	1.360	6.60
2	Single.	15	5,107	1,008	7.20
2	Double.	15	4,605	1,415	4.80
3	Single.	14	3,730	841	10.18
3	Double.	15	4,173	1,414	5.96
Average.	Single.	. .	4,536	918	9.09
Average.	Double.	. .	4,101	1,396	5.79

The average ultimate strength per inch of width for single belts, as shown by the tests, 918 pounds, is considerably larger than the value usually assigned, while the ratio of the strength of double to single belting is $\frac{1,396}{918}$, or about $\frac{10}{6.58}$, the ratio generally used being $\frac{10}{7}$. It must be remembered, however, that the belting used in the experiments was all of the first quality, so that the average strength of belting sold in the market would be less than those given above.

One of the facts most noticeable in the experiments was the greater uniformity of double belting in strength and in elasticity, due, no doubt, to the fact that it is composed of two layers whose irregularities tend to neutralize each other. The single belts in nearly every instance showed a tendency to stretch more on one edge than on the other, and broke by tearing on the weaker edge, showing that edge to have been nearer the flank of the hide in the cutting. See Fig. 2, No. 41.

In the double belting this was less noticeable.

The strength per square inch of cross-section, as shown by Table I, is somewhat less for double belts than for single.

In every case the strongest samples showed the smallest percentage of elongation.

The experiments showed conclusively the disadvantage of using rivets in making double belts. The double belts in Series Nos. 1 and 3 had rivets at intervals, while those in Series No. 2 were simply cemented.

In nearly every case where rivets were present the fracture commenced at a rivet hole. See Fig. 2, Nos. 79, 80, and 83.

Several experiments were made on joints in single belts, and the results are given in Table II. The only cemented joint tried, that of No. 44, shows a greater strength per inch of width than any of the riveted joints.

The riveted joints (see Fig. 3) show an average strength per inch of width of 622 pounds, or about two-thirds the average of the strength of the single belts tested, while the cemented joint broke at 1,112 pounds per inch of width, being a little stronger than the average of the belt samples in that series.

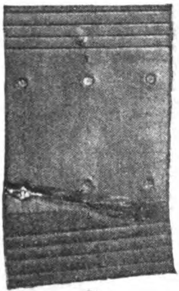
TABLE II.—BELT JOINTS.

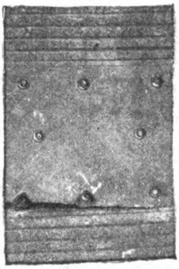
SAMPLE NO.	LENGTH OF LAP.	NUMBER OF RIVETS.	TOTAL BREAKING LOAD.	LOAD PER SQUARE INCH. CROSS-SECTION.	LOAD PER INCH OF WIDTH.	PER CENT. OF ELONGATION.
	Ins.					
7	5	6	4,170	3,940	709	7.5
8	4.6	6	3,610	3,000	611	7.5
72	7.2	9	4,520	3.545	762	5.5
73	5.1	8	2,420	1,792	406.8	7.5
44	Cemented.		4,380	5,560	1,112	7

As may be seen from Fig. 3, the riveted joints always failed at rivet holes.

The principal conclusions to be drawn from these experiments are: 1st, that double belts are superior to single in respect of their greater uniformity and less liability to become crooked by reason of uneven stretching, and 2d, that a belt can be made stronger without the use of rivets, either at joints or elsewhere, if good cement is used, and a proper degree of pressure is applied. Doubtless in situations where a belt is much exposed to dampness, rivets might be necessary at the edges of the splices to prevent starting up.

In case ordinary double belts are too heavy or too stiff for the required service, a light double belt may be obtained, which will be no heavier than a single, and much more uniform.

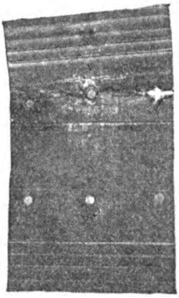

7

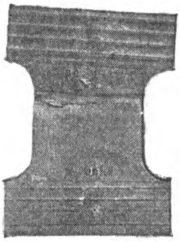

73

79

41

72


8


80

83

Several experiments were also made on some single belting of the same quality as Series No. 1, to determine the transmitting power. A four-inch single belt, running on 24 inch pulleys, at an average speed of 868 feet per minute, developed in four trials an average of eight horse-power with a slip of only five feet per minute.

The tension on the tight side was 88 pounds per inch of width, and on the slack side only 22 pounds, the coefficient of friction averaging about .40.

The number of square feet of belt per horse-power per minute was only 44.

The horse-power developed is nearly double that generally allowed for four-inch belts at such a speed, but if the belt were endless, cemented without rivets, the factor of safety would be about 10. I am inclined to believe that many of our belt formula are based rather on the strength of poor joints than of good leather.—*American Machinist.*

CHILLING TEST PIECES WITH LIQUID CARBONIC ACID.

Writing on the use of liquid carbonic acid gas for chilling test pieces, especially stone, iron, and steel, at low temperature, M. Ph. v. Haller, in the *Industrial Zeitung* of Riga, says that a cheap and simple form of apparatus in which the test specimens could be cooled, would consist of a wooden box with double walls, top and bottom, the spaces between being filled with some non-conducting substance. The liquid gas could be led into such a box from the iron and steel flasks in which it is furnished, and would be deposited in great part in the form of frost at a temperature of about 78° Centigrade. The test specimens could be readily put into and taken from such a box, and would quickly get a low temperature. One of the Russian railroad companies is on the point of having such an apparatus constructed for testing rails and wheel tires at low temperature. The possibility of accomplishing the desired object with such an outfit—viz., the rapid freezing of specimens, was demonstrated by putting a number of iron test pieces into a bag of several thicknesses of coarse cloth and then introducing the liquid gas. This at once became solid and filled all the spaces between the specimens which thus lay packed in snow. Each specimen was provided with a depression into which mercury could be poured, and in doing this, after a short exposure in the freezing bag, it was found that the mercury immediately solidified, showing, in the absence of a suitable thermometer, that the temperature of the specimens was certainly below 39° Centigrade, if not lower. At the St. Petersburg Laboratory of Experimental Medicine a cold room of quite large proportions has been fitted up, in which also liquid carbonic acid is the cooling agent.—*Railway Review.*

ABRASION OF HORSE HAIR.

While we feel that the subject of abrasion of horse hair is hardly an appropriate topic for discussion in a journal devoted to physical testing, we think the following will prove of sufficient interest to our readers to pardon the digression.

Of course every one knows that the hair used in making a violin bow is taken from the tail of a horse, but just why some bows give so much sweeter chords than others has, to a greater or less extent, always remained a trade secret.

In passing the finger over a horse hair in one direction a slight roughness is observed very similar in character to the barb of a fine fish-hook. In order to bring out the proper tone from a violin and that the up stroke of the bow will give the same tone as the down stroke, these millions of infinitesimal points are arranged to point in opposite directions. In other words, the hairs are placed in the bow end for end, so as to cause the same amount of friction whichever way the bow is drawn. Artists appearing in public who are noted for the superior quality of tone of their instruments, are very particular upon this point; in fact many of them "re-hair" their bows themselves, and will allow no one to do it for them. When this roughness of the hair wears off a most decided difference of tone is at once noticed and the hair cast aside. It is said that some of the most noted violinists will "re-hair" their bows for every concert, not daring to run the risk of losing their reputation by using a bow that does not contain entirely new hair.

Brick Dust Cement.—Attention has been repeatedly called to the fact that brick dust is very generally used in Spanish countries in place of hydraulic cement for building purposes. A correspondent of the *English Mechanic* says that "throughout the East this material appears to have been in use as an ingredient in their notably durable mortars and cements from times unknown." The bricks, he says, are pulverized by a stamp worked by man or woman-power, and this powder then passed through a sieve.—*American Engineer.*

TESTS OF IRON AND STEEL.

The American Society of Civil Engineers appointed a committee some time ago to consider and report on "Uniform methods of testing materials used in metallic structures and on requirements for these materials to further improve the grade of such structures." The majority of the committee, consisting of Messrs. James G. Dagron, Robert W. Hunt, Henry B. Seaman, and William H. Burr submitted the following report, which, besides being interesting, will probably result in considerable discussion, especially on account of the minority report which is appended:

"Standard specifications for uniform methods of testing material used in metallic structures should be of such general character as will meet the requirements of usual conditions, so that their adoption may best subserve a more nearly uniform practice in shops and mills, and at the same time leave the engineer free to meet the special needs of any unusual conditions by supplementary or other specifications; hence the following recommendations have been framed with those ends in view.

"Inasmuch as cast and wrought iron, rolled steel and steel castings are the most commonly used in metallic structures, your committee decided to restrict its functions to the consideration of those materials. A thorough examination of a large number of existing specifications, as well as the leading literature upon the subject, supplemented by correspondence with material producers in some special cases, has led your committee to the following conclusions and recommendations:

"*Cast Iron.*—The infrequent use of this material justifies only the most simple and convenient tests; hence, we recommend the transverse tests of a specimen 2 by 1 inch section and 27 inches long, resting flatwise on dull knife-edge supports 24 inches apart, centres, with an applied weight of 2,000 pounds or more, midway between them. The specimen, if of satisfactory strength when cast under the same circumstances as those which attend the casting of the full-size piece, must carry at least the minimum weight named above, and exhibit, when broken, the fracture of gray iron of good quality. Failure shall be produced in not less than two minutes nor more than five minutes from application of the first load, and the bar must show a centre deflection before breaking of at least .3 inches, and must indicate a good quality of gray iron.

"*Wrought Iron.*—Although the answers received from our letter of inquiry do not indicate that the members of the society in the aggregate place a very high value upon the reduction of area of the fractured section, your committee believes that the requirement of a proper value for it should be prescribed. Its value is always easily ascertained and its indications may at times be of considerable importance.

"The committee also recommends that the expression 'elastic limit' be confined in its use to its original meaning, since its more general adoption leads to ambiguity and to useless discussion and dissension. The usual methods of testing indicate the first strength or 'yield point' of the material, and in order to avoid the objections already mentioned the committee has confined itself to the expression 'yield point' when applied to practical testing. The 'drop of beam' is considered sufficiently accurate to determine the 'yield point,' but the increased accuracy of autographic records, or use of instruments of precision, is recommended.

"Experimental investigations show that the relative dimensions of a test piece become of little practical consequence if the gauged length exceeds about four times the greatest diameter of the specimens. It is, therefore, recommended that a minimum gauged length of eight inches be used for the general practice of testing specimens, with a distance of not less than 12 inches between shoulders of the specimen, or between the jaws of the testing machine. Under these conditions, however, it is understood that the gauged length shall in no case be less than four times the greatest diameter of the test piece, and that the minimum thickness shall be one-fourth inch; also that the sectional area of test piece shall not be less than one half square inch. In obtaining the final elongation the curves of reduction each side of the point of fracture should be included in the measured length.

"In testing it is recommended that the load be applied continuously and at a rate as nearly as practicable of 4,000 to 5,000 lbs. per square inch per minute below the yield point, and of 7,000 to 8,000 lbs. above the yield point.

"It is recommended that the ordinary bending test be continued, and that it be made rapidly with pressure, rather than with blows of a hammer, as the results are thereby more comparable. The nicked bending or fracture test, however, does not show any essential property of the material which would not be disclosed by the tests already mentioned, and hence its adoption is not recommended.

"For the requirements of wrought iron with the tests outlined, the following are recommended:

	Bars per Square Inch.	Tension Plate, Angle, and Other Sh'pes.	Compression Pl'te, Angles, and Other Shapes.	Web Plates.
Yield point, ...	26,000	26,000	26,000	26,000
Ultimate, ...	50,000	48,000	48,000	46,000
Elongation in 8 inches, ...	20 p. c.	15 p. c.	12 p. c.	8 p. c.
Reduction, ...	30 p. c.	20 p. c.	16 p. c.	12 p. c.

"Specimens should bend cold 90 degrees without fracture, with inner radius of bending not exceeding twice the thickness of the test piece for bar iron, nor three times that thickness for plate and shape iron.

"Rivet iron must be soft and tough, and pieces of the full diameter of the rivet must be capable of bending cold until their sides are in close contact without showing signs of fracture.

"*Rolled Steel.*—The methods of testing wrought iron may, in general, be applied to rolled steel. In addition to these, however, the quenching test may be used to advantage, by which a specimen heated to cherry red is to be quenched in water of 82 degrees F., and then tested as usual.

"The drifting test is not recommended as a requirement for quality and the annealing test is recommended only for full-size eye bars.

"For the requirements of rolled steel it is recommended that a mean ultimate resistance be specified for each grade of steel, and that the ultimate resistance of the test specimen should not vary more than 4,000 lbs. per square inch either way from the resistance specified. It is also recommended that the yield point, the elongation, and the reduction of area each be a function of the ultimate strength found in the test specimen.

"The following requirements are recommended for the various grades of steel:

ULTIMATE STRENGTH PER SQUARE INCH.

Low steel,	60,000 pounds plus or minus 4,000
Medium steel,	65,000 pounds plus or minus 4,000
High steel,	70,000 pounds plus or minus 4,000

Yield point = 55 per cent. of the ultimate resistance of specimen.

$$\text{Per cent. elongation in 8 inches} = \frac{1{,}500{,}000}{\text{Ultimate.}}$$

$$\text{Per cent. reduction of area} = \frac{2{,}800{,}000}{\text{Ultimate.}}$$

"Rivet steel when heated to a low cherry red and quenched in water at 82 degrees F. must bend to close contact without sign of fracture. Specimens of low steel when treated and tested in the same manner must stand bending 180 degrees to a curve whose inner radius is equal to the thickness of the specimen without sign of fracture. Specimens of medium steel, as cut from bars or plates and without quenching, must stand bending 180 degrees to an inner radius of one and one-half times the thickness of the specimen without sign of fracture; while those of high steel, also without quenching, must stand bending 180 degrees to a radius of twice the specimen without sign of fracture.

"*Steel Castings.*—In steel castings the tension test is recommended, with the following requirements:

	Pounds per square inch.
Ultimate,	65,000
Yield point,	35,000

Elongation in 8 inches = 15 per cent.
Contraction = 25 per cent.

"*Full-Size Members.*—It is deemend inadvisable at present to recommend any special requirements for full size members, as it is considered preferable to leave those requirements for specification by the engineer."

Mr. Percival Roberts, Jr., submitted the following minority report:

"The points upon which I disagree I hardly think it necessary to touch upon at present, for, as a result of considerable deliberation, I do not deem it advisable to recommend to the Society any definite set of specifications, believing it to be the prerogative of the engineer, as of any other professional man, to select and specify such tools and methods of procedure as he deems most expedient and suitable for the case with which he deals; but I do recommend that whenever possible, and wherever he may not have particular features to introduce, or peculiar conditions to meet, that he specify for his material a grade which may be in general use by the majority of engineers, as by so doing he is more certain of obtaining a uniform product, and of reducing the delays of manufacture to a minimum—two points which are of the greatest importance to both engineer and manufacturer.—*Railway Review.*

A STUDY IN DENSITY.

Perhaps there is nothing that so clearly explains the intense ignorance of the Turks as the fact that the Censors of Turkey prohibit the importation of all educational books, this state of affairs being brought about by the discovery in one book of the formula H_2O, which the wise men of the court interpreted to mean "Hamid II is naught—a cipher—a nobody."

THE PHYSICAL QUALITIES OF ACID OPEN-HEARTH NICKEL STEEL.*

BY H. H. CAMPBELL.

The strength of a bridge of a given weight and design, the weight of a bridge of a given strength and design, and the longest span possible under a given design, are all limited by the elastic strength of the material used. These well-understood axioms point naturally to the use of steel possessing a high elastic limit, but this tendency is opposed by the no less well-known fact that, as the elastic strength of steel is increased by ordinary strengthening influences, there is a reduction either in the static or the shock ductility. It is true that an increase in brittleness under shock is not always shown by the ordinary system of tests, but broad generalizations from general experience have led engineers to avoid metal of high strength. Within recent years certain experiments by the United States government upon armor plates have proved quite conclusively that an alloy of nickel with steel will give a metal possessing a high ultimate and elastic strength with an exceptional toughness. Moreover, these experiments seem to show that the metal is pre-eminently fitted to withstand the effects of sudden shock.

The manufacture of nickel steel is attended by a considerable increased cost, arising from the cost of nickel itself, which, although quoted at the lowest price that has ever been known, is now sold at thirty-five cents per pound. Inasmuch as the steel should contain about three per cent. of this element, it is easy to see that the cost, under the present conditions of nickel production, must prohibit the use of the new alloy for ordinary purposes. It has probably occurred to many engineers, however, that under certain circumstances, as in the construction of long-span bridges, the extra cost per pound might be much more than counterbalanced by the diminution in the weight, particularly of the tension members.

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* Read before the American Society of Civil Engineers.

Before venturing to use such a new material the conservative engineer would ask for some definite information on its physical qualities when rolled into plates, angles, and rods, under the conditions of every-day practice. To furnish this information the Pennsylvania Steel Company has made a heat of nickel steel, and has rolled it into common structural shapes, the results being herewith presented. It has also made similar shapes of low phosphorus acid open-hearth steel without nickel. These two kinds of steel were rolled in the same mills, and were tested in the same machines and by the same operator, so that the results are fairly comparable. In order that such an investigation should be conclusive it would be necessary to make a large number of heats and several tests from each heat, but that is almost out of the question in the case of the nickel steel on account of the expense involved and the fact that there is no present market for the product. On this account only four tons of metal were made.

Two ingots were cast of the nickel steel, one of which had a cross section of 18x20 inches, and the other 16x20 inches. The larger ingot was rolled into four slabs with a cross-section of 16x5 inches, and two of these were rolled in the universal mill of the Central Iron Works, Harrisburg, Pa., and two were rolled in the plate mill of the Paxton Rolling Mills, Harrisburg, Pa. Both mills made one three-eighth inch plate and one one-half inch plate. The amount of reduction on these slabs from the ingot was not so great as might be desired, and it would have been better if a larger ingot and a thicker slab had been used; but as the whole charge weighed only four tons, a larger ingot was out of the question. The smaller ingot was rolled partly into blooms and partly into billets. The blooms were rolled by the Pennsylvania Steel Company into angles of different sizes, while the billets were rolled into rivet rods at the same works.

The rods, angles, and plates of the high steel containing no nickel, which is called "hard forging steel" in the tables, were rolled from such blooms and slabs as happened to be on hand at the time, and hence were from different charges. They were made from ingots varying in cross-section from 16x20 inches to 24x32 inches.

There are also given the results obtained on a lot of steel which was used for the construction of the massive gates now being placed in the Cascade Canal locks on the Columbia River in Oregon. There are four of these gates, each consisting of two leaves, each leaf being 51 feet wide and from 37 to 55 feet deep. The steel was made by the Pennsylvania Steel Company, while the gates were built by the Maryland Steel Company. The fact that the metal was of unusual strength will render the figures valuable for comparison. The specifications required that one piece of an angle should open out flat, while another piece should close shut, without fracture. In the case of plates, a strip was to bend double around a curve whose radius was equal to one and one-half times the thickness of the piece. As a matter of fact, each test was bent flat upon itself, and out of 3,000 tons of material there was not a failure of a test piece or angle or of plate. The specifications called for an ultimate strength of between 70,000 and 80,000 pounds per square inch, but the accompanying table gives only those heats that ran between 75,000 and 80,000 pounds. This metal is called "forging steel" in the tables.

Table No. 1 gives the results of the test of nickel steel, while Table No. 2 places the records of the three grades in more convenient form for comparison. The elastic limit was found by the drop of the beam. This was readily determined in the case of the nickel steel and of the softer "forging steel," but was not well marked in the plates of the "hard forging steel." In the case of the "forging steel" there are some data lacking. This arises from the fact that the figures given are records of steel made and tested more than a year ago, and there was no need at the time of having this particular information. The results are rather disappointing in showing a less superiority of the nickel steel than may be commonly supposed. Special methods of heat treatment might be made to show better results, but if this plan is followed in the case of one grade of steel it should be followed in all others. Judging from the records given, it seems doubtful if nickel steel offers such marked improvement in quality that it can be employed profitably in ordinary engineering work.

TABLE No. 1.—Physical Properties of Acid Open Hearth Nickel Steel.

Made by the Pennsylvania Steel Company. Composition, C, 0.24; Mn, 0.78; S, 0.027; P, 0.032; Ni, 3.25.

SHAPE OF MEMBER.	SIZE OF MEMBER.	ULTIMATE STRENGTH. LBS. PER SQ. IN.	ELASTIC LIMIT. LBS. PER SQ. IN.	ELASTIC RATIO. PERCENTAGE.	ELONGATION IN 8 INS. PERCENTAGE.	ELONGATION IN 2 INS. PERCENTAGE.	RED'CT'N OF AREA. PERCENTAGE.
Rounds, ...	¾″ diam.	86,220	64,140	. .	20.00	34.00	45.6
	¾″ diam.	85,960	63,100	. .	20.00	34.00	45.5
	¾″ diam.	85,720	63,580	. .	20.50	34.00	48.1
	¾″ diam.	86,160	63,480	. .	20.25	34.00	46.1
	Average, .	86,015	63,575	73.9	20.19	34.00	46.3
Angles, ...	3″ x 3″ x ⅜″	88,600	59,720	. .	19.75	37.00	49.2
	3″ x 3″ x ⅜″	85,280	57,800	. .	22.00	41.00	51.5
	3″ x 3″ x ½″	87,000	58,140	. .	23.50	41.00	50.7
	Average, .	86,960	58,553	67.3	21.75	39.67	50.5
Universal plates, ... Longitudinal tests, . . .	⅜″ x 16″	84,080	57,320	. .	21.25	40.00	53.1
	⅜″ x 16″	85,140	59,240	. .	21.75	39.00	54.2
	⅜″ x 16″	86,480	59,000	. .	19.25	37.00	47.8
	½″ x 16″	86,200	58,260	. .	21.00	40.00	54.1
	½″ x 16″	86,660	58,320	. .	21.00	39.50	52.3
	½″ x 16″	86,080	58,320	.	22.25	40.00	50.5
	Average, .	85,773	58,410	68.1	21.08	39.25	52.0
Universal plates, ... Transverse tests, ...	⅜″ x 16″	84,460	57,560	. .	14.50	27.00	40.6
	⅜″ x 16″	87,020	58,440	. .	14.50	26.00	36.8
	⅜″ x 16″	87,440	59,000	. .	15.75	31.00	39.1
	½″ x 16″	86,300	58,160	. .	18.50	34.50	41.6
	½″ x 16″	86,360	57,900	. .	16.25	25.00	25.6
	½″ x 16″	86,920	58,160	. .	19.50	30.00	33.0
	Average, .	86,417	58,203	67.4	16.50	28.92	36.1
Sheared plates, ... Longitudinal tests, . . .	⅜″ x 44″	86,520	59,560	. .	20.50	37.00	52.6
	⅜″ x 44″	84,440	58,800	. .	19.50	37.00	48.8
	⅜″ x 44″	86,680	59,640	. .	17.00	31.50	42.8
	⅜″ x 44″	85,640	57,600	. .	16.75	32.50	40.0
	½″ x 44″	84,020	57,600	. .	20.50	39.00	52.2
	½″ x 44″	84,880	57,180	. .	19.75	37.00	51.5
	½″ x 44″	85,180	56,800	. .	19.00	34.50	50.2
	Average, .	85,337	58,169	68.1	19.00	35.50	48.3
Sheared plates, ... Longitudinal tests, . . .	⅜″ x 44″	85,120	57,680	. .	17.00	26.00	34.3
	⅜″ x 44″	83,840	58,380	. .	19.00	34.00	42.5
	⅜″ x 44″	83,630	58,040	. .	18.50	35.00	42.8
	½″ x 44″	83,520	55,220	. .	16.00	34.00	48.0
	½″ x 44″	84,520	56,980	. .	15.50	32.00	47.0
	½″ x 44″	85,630	. .	. .	16.75	34.00	45.7
	Average, .	84,377	57,260	67.9	17.13	32.50	43.4

TABLE No. 2.—Summary of the Averages Given.

Shape of Member.	Kind of Steel.	Ultimate Strength. Pounds per Square Inch.	Elastic Limit. Pounds per Square Inch.	Elastic Ratio. Percentage.	Elongation in 8 Ins. Percentage.	Elongation in 2 Ins. Percentage.	Reduction of Area. Percentage.
Rounds, ...	Nickel, . . .	86,015	63,575	73.9	20.19	34.00	46.3
	Hard forging,	87,663	58,055	66.2	16.70	24.44	30.3
	Forging, . .	78,066	51,793	66.3	23.94	. . .	52.0
Angles, ...	Nickel, . . .	86,960	58,553	67.3	21.75	39.67	50.5
	Hard forging.	87,820	54,153	61.7	19.25	34.83	43.3
	Forging, . .	76,970	49,544	64.4	.	. . .	49.6
Universal plates, Longitudinal, . .	Nickel, . . .	85,773	58,410	68.1	21.08	39.25	52.0
	Hard forging,	82,773	50,163	60.6	20.50	37.67	47.0
	Forging, . .	78,996	46,654	59.1	26.78	. . .	52.1
Universal plates, Transverse, . . .	Nickel, , .	86,417	58,203	67.4	16.50	28.92	36.1
	Hard forging,	85,173	(50,000)*	(58.7)*	18.83	23.17	27.4
	Forging, . .	. . . .	. . . . .	. . .	. .	. . .	. .
Sheared plates, Longitudinal, . .	Nickel, . . .	85,337	58,169	68.1	19.00	35.50	48.3
	Hard forging,	85,012	(50,000)*	(58.8)*	22.10	39.40	48.4
	Forging, . .	78,918	49,128	62.3	22.03	. . .	50.8
Sheared plates, Transverse, . . .	Nickel. . . .	84,377	57,260	67.9	17.13	32.50	43.4
	Hard forging,	84,327	(50.000)*	(59.3)*	21.71	37.00	41.3
	Forging, . .	. . . .	. . . . .	. . .	. . .	. . .	. .

*Approximate. Could not determine accurately.

The hard forging steel contained 0.30 to 0.35 carbon; 0.60 to 1.00 of manganese; 0.03 to 0.05 sulphur, and 0.03 to 0.05 phosphorus. The forging steel carried 0.25 to 0.30 carbon, 0.6 to 0.8 manganese, 0.03 to 0.07 sulphur, 0.03 to 0.06 phosphorus, and 0.2 to 0.4 copper.—*Iron Age.*

PROFESSOR J. B. JOHNSON called attention to the fact that for all commercial purposes the three points, elastic limit, yield-point, or break-down point, were one and the same, and need only be considered separately in an abstract scientific study of the subject. He showed charts from tests recently made by Professor Gray at Terre Haute, made on what is perhaps the best apparatus in existence for the purpose. They showed a practically straight line from the origin to the yield-point.

HEAT TESTS FOR CEMENT.

The results of the experiments of Professor Tetmajer, of Zurich, to ascertain the efficiency of heat tests for determining the soundness of cements, which are summarized on another page, deserve the careful consideration of engineers. These tests have the valuable feature of being comparable with the action of the same cements tested under normal conditions. A cake of each cement tested by heat was also placed in cool water and in moist air for a period of three years, for the purpose of determining whether the slower action of disintegration under normal conditions would confirm the results obtained by the very rapid action induced by heat. With the exception of the experiments by Mr. Fred P. Spalding, M. Am. Soc. C. E. (*Engineering News*, August 24th, 1893), which were much less comprehensive, these are the only tests in which this valuable feature has been introduced. The opponents of heat tests have made much of this weak point in the tests made in the past, and it is gratifying to note that it is being studied with the view of definite settlement. Taken as a whole, Professor Tetmajer's experiments cannot be called decisive, although they serve to establish heat tests on a firmer basis and give much hope of establishing ultimately their reliability as a practical test for the soundness of cements. It is also interesting to note that the boiling-water test is fully as efficient as the more severe kiln and flame tests. As we noted in the discussion of Mr. Spalding's tests, the total dehydration of a cement briquette by baking or by heating it red hot seems illogical, considering the important part which moisture is supposed to play in the hardening of cement, even after the so-called final setting. We are inclined to believe that a hot-water test—that is, with the temperature considerably below 212°, or boiling—will be fully as efficient as the boiling test. Mr. H. Le Chatelier seems to sum up the heat test pretty fairly when he says: "No hydraulic lime or cement notoriously bad can escape the boiling test. It remains to prove that all cements unable to stand the test are really bad."—*Engineering News*.

Our Willie now has left us,
  We ne'er shall see him more;
What Willie took for H_2O
  Proved $H_2S\ O_4$.—*Puck.*

TEST OF STEEL BALLS.

In the Department of Experimental Engineering, Sibley College, Cornell University, Ithaca, N. Y., frequent tests are made of more than passing interest. Such are the following, recently completed for the Cleveland Machine Screw Co., of Cleveland, Ohio, and reported in the October number of *The Sibley Journal of Mechanical Engineering.*

" In the first test a large variety of balls was presented, ranging in size from 1¼ to 2 inches. In the several lots, thirty-three in all, some eighteen or twenty special methods of hardening were used, the object of the experiments being to bring out the advantages, if any, of each process. The balls were made of high-grade steel as actually used by the Cleveland Screw Co. in their work.

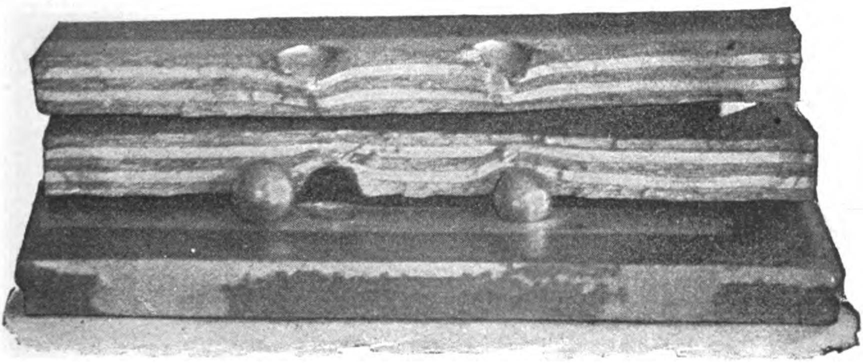
" The method of testing consisted in placing each ball between two special steel bearing plates in the testing machines, a 300,000-pound Olsen and a 100,000-pound Riehlé Brothers being used, and applying a gradual pressure until the ball was crushed. In nearly every case the pressure plates were dented to a depth ranging from about .0018 to about .0092 inch. In all, one hundred tests were made, three tests for each method of hardening. In general, a peculiar conical wedge was thrown out, with its axis coincident with the axis of strain. This, however, did not occur with hard balls, which broke into small, irregular pieces, nor with the softest ones, which split into hemispheres.

" The following table gives the tabulated data, and shows the poorest as well as the best results for each size of ball :

NO.	DIAMETER.	MAXIMUM CRUSHING LOAD. AVERAGE OF THREE TESTS.	MINIMUM CRUSHING LOAD. AVERAGE OF THREE TESTS.	NUMBER OF SETS OF 3.
1	¼ in.	10,683	5,566	21
2	3/16 "	3,500	2 923	3
3	5/16 "	11,026	7,460	3
4	⅜ "	17,690	. . .	1
5	½ "	39,766	. .	1
6	¾ "	30,426	23,990	3
7	1 "	55,210	. . .	1
8	2 "	220,000	Only 1 ball tested.	. .

" In the second test the balls were all ¼ inch in diameter. Four varieties of steel were represented, and ten tests of each grade were made, a small 15,000 Olsen machine being used. Notwithstanding the fact that the best grade of steel, tempered as hard as possible, was used for the pressure plates, denting was observed, as in the first experiment. The following table shows the individual difference in strength of balls and indentation. The two lots made of Kidd's steel average closely the same, but are nearly 10 per cent. lower than the Crescent steel ones, while the Jonas & Colver steel is about 20 per cent. less than the Crescent:"

No.	Lot 1, Kidd's.		Lot 2, Kidd's.		Crescent.		Jonas & Colver.	
	Pounds.	Indent.	Pounds.	Indent.	Pounds.	Indent.	Pounds.	Indent.
1	7,495	.0084	7,512	.0009	8,195	. . .	6,410	.0055
2	9,905	.0090	6,905	.005	6.960	.0057	6,725	.0096
3	4.485	.0036	7,300	.001	6,000	.0065	7 080	.0019
4	8,010	.0044	8.520	.0014	9,000	.0099	6,250	.0057
5	6 000	.0039	6,790	.0017	8,995	.0078	6,305	.0031
6	6,880	.0018	8,370	.001	9 460	.0055	6.510	.0065
7	6,715	.0072	7,365	.0044	8.515	.0062	6,510	.0061
8	7,500	.0037	6,977	.0014	6.675	.0055	4,000	.0038
9	6,265	.0010	7,283	.001	7.770	.0058	6,965	.0030
10	6,840	.0059	6,735	.0061	8,740	.0060	6,510	.0081
Av.	7,009 5		7,375.7		8,031		6,326.5	



The illustration, kindly loaned by *The American Machinist*, shows fracture produced in a material used in burglar-proof safes and consisting of alternate layers of hardened chrome steel and wrought iron welded together. Two ½-inch balls had been placed between the plates and a load of 124,000 pounds gradually applied, which fractured the plate although scarcely affecting the balls.

EXPERIMENTS ON NICKEL STEEL.

Owing to the supposed difficulty of working nickel steel, it has never come into as common use as its merit would seem to warrant. This fact is greatly to be regretted, as the following tests, made by one of our government inspectors thoroughly experienced in this class of work, show conclusively that nickel steel is vastly superior to carbon steel of the same chemical and physical qualities:

C. .22, Si. .009, P. .064, S. .025, M. .648, Copper, .058, Nickel, 3.154.

Diameter,	.777	797
Area per square inch,	.4742	.4989
E. L. gauge,	26,200	23,300
E. L. per square inch,	55,250	46,700
Ult. gauge,	38,500	37,400
Ult. per square inch,	81,190	74,970
Reduced area,	.2827	.2410
Per cent. reduction,	40.3	51.6
Per cent. elongation in 8 inches,	18.25	17.87

A piece of this material, 1¼ inches thick, was forged cold to ½ inch, and another piece heated and forged from 1¼ inches square to ¼ inch, and then allowed to become a blue heat, when it was reduced to a knife edge. Neither showed signs of fracture.

COMPARISON TESTS OF STEEL.

3-INCH SQUARES AND 2½ INCH BY 2½ INCH ANGLES.

3-inch Squares, Basic O. H., C. .13, P. .037, M. .57, S. .018.

Diameter,	.504	.500	.504	.504
Area per square inch,	.199	.196	.199	.199
E. L. gauge,	7,200	6 990	7,100	7,200
E. L. per square inch,	36,190	35,590	35,590	36,190
Ult. gauge,	12,200	12,000	12,200	12,200
Ult. per square inch,	61,150	61,130	61,150	61,150
Reduced area,	.0934	.0855	.0907	.0855
Per cent. reduction,	53.1	56.5	54.5	57.1
Per cent. elongation in 2 inches,	34.	35.	33.	35.

2½ INCH BY 2½ INCH ANGLES, SAME HEAT, TESTED IN □ SECTION.

Area,	.449	.450	.449	.448
E. L. gauge,	16,400	16,800	17 000	17,100
E. L. per square inch,	36,530	37,330	37,860	38,170
Ult. gauge,	32,000	32,530	32,800	32,000
Ult. per square inch,	71,270	72,220	73,050	71,430
Reduced area,	.224	.257	.218	.218
Per cent. reduction,	50.1	42.8	51.4	51.3
Per cent. elongation in 8 inches,	26.75	25.75	26.00	26.50

4-INCH SLABS AND 3-INCH HULL PLATES.

SLABS, C. .10, P. .026, M. .35, S. .034.

Diameter,	.500	.500	.500	.500
Area per square inch,	.1963	.1963	.1963	.1963
E. L. gauge,	6,300	6,400	6,300	6,300
E. L. per square inch,	32,090	32,600	32,090	32,090
Ult. gauge,	10,200	10,200	10,200	10,300
Ult. per square inch,	51.600	51,600	51,600	52,470
Reduced diameter,	.280	.276	.275	.275
Reduced area,	.0616	.0598	.0594	.0594
Per cent. reduction,	68.6	69.5	69.7	69.7
Per cent. elongation in 2 inches,	42.	40.	44.	41.

HULL PLATES, SAME HEAT, TESTED IN □ SECTION.

Area per square inch,	.506	.498	.492	.492
E. L. gauge,	17,690	17,430	17,380	18,500
E. L. per square inch,	34,780	35,000	35,320	37,600
Ult. gauge,	27,600	27,030	26,150	26,560
Ult. per square inch,	54,550	54,280	53,150	53,990
Reduced area,	.239	.213	.207	.187
Per cent. reduction,	52.7	57.2	57.9	61.9
Per cent. elongation in 8 inches,	26.25	27.	29.75	26.50

INSTEAD of using steel wire with a maximum tensile strength of 150 tons per square inch for the North River bridge, a No. 3 B. W. G. wire of 90 tons tensile strength is proposed on account of the prohibitive cost of the higher strength, as against wire of 85 tons in the Brooklyn bridge. An ideal span is a cable of 6,000 parallel steel wires of No. 3 B. W. G., having a breaking tensile strength of 28,440 tons. The working strength of such a cable would be 9,480 tons. In the proposed structure sixteen such cables would be used.—*Engineering Mechanics.*

TESTS OF SIGNAL PIPE CONNECTION.

In a recent paper by Mr. H. D. Miles, before the Railway Signaling Club, reference was made to tests which had been made to determine the relative strengths of galvanized and plain signal pipe, both in tension and compression, and also to compare steel with iron as a material for this purpose. These tests were made at the Pittsburg Testing Laboratory, and the results obtained are given in the accompanying tables. Two tensile tests were made with galvanized and ungalvanized iron pipe and two tests of the same pipe coupled. Similar tests were made of the steel pipe except that one each of the galvanized and ungalvanized pipe was made. The compression tests were made in two lengths, one being approximately two inches and the other twelve inches. Cold bending tests were also made which showed the material to be good, as both the iron and steel bent 180 degrees, without fracture.

Tensile Tests of One Inch Pipe.

Description.	Elastic Limit.	Tensile Strength.	Elongation. Percentage in 8 Ins.	Fracture.	Remarks.
	Lbs.	Lbs.			
1 in. Steel Pipe, plain, . . .	15,540	25,080	33.2	Silky.	
1 “ “ “ “	16,000	24,700	30.25	“	
1 “ “ “ galv., . . .	15,650	26,840	30.0	“	
1 “ “ “ “	15,650	26,870	29.25	“	
1 “ “ “ gal., 1 in. c'ple,	15,720	21,180	5.6	“	Broke in Thread.
1 “ “ “ plain,“ “	14,800	20,300	3.2	30% gran.	“ “ “
1 “ Iron “ “ “ “	16,000	24,150	6.2	50% cryst.	“ “ “
1 “ “ “ galv.,“ “	14,650	22,900	3.7	Cryst.	“ “ “
1 “ “ “ “ “ “	14,100	22,510	4.5	“	“ “ “
1 “ “ “ plain,“ “	16,570	24,800	6.2	Fibrous.	“ “ “
1 “ “ “ galv., . . .	14,600	22,680	20.0	“	
1 “ “ “ “	13,550	22,650	16.7	“	
1 “ “ “ plain, ...	15,960	26,650	22.5	“	
1 “ “ “ “	15,710	25,130	22.0	“	

Both iron and steel bent 180 degrees flat.

The criticism which is generally made in regard to galvanized pipe, is that it is softened by the galvanizing treatment, but these tests do not confirm this. The compression tests show that the galvanized and ungalvanized wrought-iron pipe began to compress at about the same load, but that the ungalvanized pipe showed greater strength at the failing point. A considerable advantage was shown by the galvanized steel pipe over that which was ungalvanized, both at the point of compression and at the failing point. The tensile tests show that galvanizing gives lower elastic limits and tensile strength in wrought-iron pipe, while with the steel they are about equal as to elastic limit and the tensile strength of the galvanized pipe is greater. The criticism referred to is therefore unfounded, and in fact the assumption that galvanizing necessarily weakens the pipe is shown to be erroneous. The steel pipe, beside having a somewhat higher tensile strength, has a much higher elongation, and other things being equal, this material would probably be the better one to use, and there seems to be no question as to the advisability of galvanizing where the additional first cost is not an objection.—*The Railway Review.*

Compression Tests of One Inch Pipe.

DESCRIPTION.	HEIGHT OF SPECIMEN.	BEGAN TO COMPRESS.	LOAD APPLIED.	DIMENSIONS AFTER LOAD APPLIED.	SPECIMEN FAILED.
	Ins.	Lbs.	Lbs.	Ins.	Lbs.
1 inch Iron Pipe, plain,	2	16,000	34,000	1.82	38,000
1 " " " "	2.04	15,000	34,000	1.88	39.250
1 " " " galvanized,	2.05	15,000	34 000	1 85	36,200
1 " " " "	2.10	17,000	34.000	1 94	38,000
1 " " " "	12.1	20 000	. . .	. . .	21,800
1 " " " "	12.05	20.000	. . .	. . .	22,000
1 " " " plain,	12.0	20,000	. . .	. . .	20,000
1 " " " "	12 05	19,000			20,805
1 " Steel " "	2.0	16,000	30 000	1.60	30,400
1 " " " "	2.0	16 500	30,000	1 68	30,500
1 " " " galvanized,	2.02		34,000	1.82	36,600
1 " " " "	1.98	20.000	34,000	1.82	36,700
1 " " " "	11 95	17.000	. . .	. . .	20,000
1 " " " "	11.97	16.000	. . .	. . .	20.000
1 " " " plain,	12.0	17,000	. . .	. . .	18,000
1 " " " "	12.0	16,000	. . .	. . .	18,000

PROPERTIES OF CAST IRON.

BY W. J. KEEP, DETROIT, MICH.

The following is a digest of the results of my investigations during the past year while a member of the Testing Committee of the American Society of Mechanical Engineers.

More than four tons of test-bars were made of the following sizes: ½ inch square by 12 inches long, and bars 1 inch square, 1 inch by 2 inches, 2 inches square, 3 inches and 4 inches square by 24 inches long. Various square bars of other lengths, and round bars cast flat and on end were made for both transverse and tensile test. The tests of these round bars by Columbia College Schools of Mines have not yet been reported. The conclusions which I shall present are drawn from the reports of tests of the square bars, which were made at the engineering laboratories at Sibley College, Cornell University, under the supervision of Professor Carpenter, and at Case School of Applied Sciences, by Professor Benjamin, and from complete chemical analyses of each size of test-bar, by Messrs. Dickman & Mackenzie, of Cleveland and Chicago.

The conclusions are as follows: The shrinkage of a casting varies, 1st, in proportion to the total quality of carbon in the casting; 2d, in proportion to the percentage of silicon in the casting; 3d, in proportion to the size of the casting.

Iron containing carbon will become crystalline after it changes from the fluid to the solid state. The size of the crystals will be larger if the precentage of carbon is greater.

In castings of uniform size, as for example a standard size of test-bar, the cause of the variation of shrinkage on account of a variation in the percentage of silicon is that silicon increases the tendency of carbon to enlarge the size of the grain.

It is the size of the grain which determines the shrinkage. The shrinkage of a casting is its decrease in size on account of its loss of heat—that is, the molecules of the iron lie closer together when cold than when hot.

Anything which causes a coarse crystallization causes the casting to swell. The total shrinkage that can be measured is the lessening of size due to loss of heat, minus the swell caused by crystallization, but the swell is never as great as the shrinkage, therefore the least shrinkage accompanies the coarsest grain.

The measure of shrinkage is a measure of the influence of the silicon in the casting when a standard size of test-bar is used.

By increasing the silicon in any foundry mixture the shrinkage can be decreased, and the casting can be made softer and of a darker color.

This is true at least until silicon reaches three per cent. *Silicon is the controlling element,* because it changes carbon from the combined state into graphite, thereby softening the casting, and because it increases the size of the grain, and because a further increase of silicon overcomes any contrary influence; also, because it is possible to vary silicon at will while no other chemical element can be varied with certainty.

Shrinkage varies with the size of a casting, because a large casting, by cooling more slowly than a small casting, prolongs the period during which a casting swells; therefore, of castings poured from the same iron, the larger the casting the less the shrinkage and the larger the grain. Slow cooling prolongs the period during which silicon can exert an influence. Having fixed upon a size of test-bar as a standard, *the measure of shrinkage of such a test-bar will indicate how much the silicon should be increased or diminished to produce the best castings.*

The strength of a casting depends mainly upon the size of the grain. The coarser the grain the weaker the casting, and the finer the grain the stronger the casting, provided it contains enough silicon to prevent brittleness.

Combined is a weakening element, because it causes brittleness. Rapid cooling produces a close grain but increases combined carbon, so that oftentimes the brittleness decreases strength more than the closing of the grain increases it.

In rapidly cooled castings which will always have a close grain, the silicon should be increased enough to remove all brittleness, therefore,

An increase of silicon increases the strength of small castings, and

An increase of silicon decreases the strength of large castings, because the slower cooling allows the silicon to increase the size of the grain. For these reasons: *The strength of a casting cannot be computed, by any known formula, from the strength of a test-bar of a size different from that of the casting.*

For a full discussion of this subject see Vol. XVI, *Transactions American Society of Mechanical Engineers.*

A NEW EXTENSOMETER.

BY C. H. BENJAMIN,
Case School of Applied Science, Cleveland, Ohio.

Engineers generally recognize the fact that the determination of the yielding point or elastic limit of a material is an important factor in tension tests. This has led to the invention of many devices for magnifying and measuring the elongation of test specimens. Some of these serve their purpose admirably, but are too expensive and too complicated for general use.

The accompanying cut illustrates a new form of extensometer recently designed by the writer, which is simple in construction and comparatively low in cost.

It is easily attached, needs no manipulation when in operation, and has a positive motion.

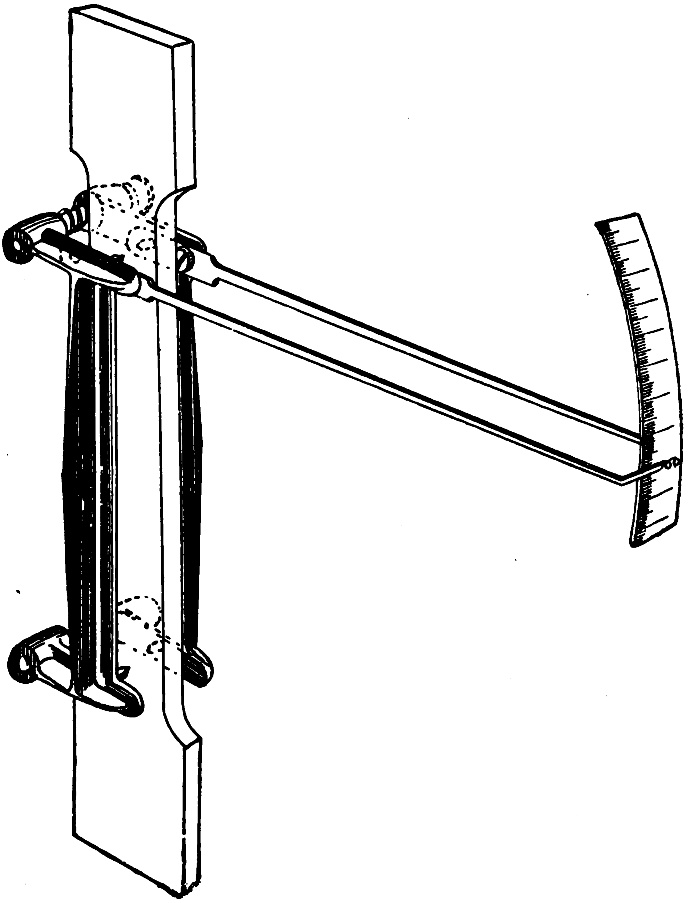
It is shown in the sketch as attached to a standard test piece of boiler plate, but may be easily adapted to round specimens. It consists of two vertical bars connected together by round studs at one side, the studs being provided with thumb nuts for closing the bars together and with spiral springs for separating them. Each bar is provided at the lower end with a steel point to bear on test specimen and at the upper end with a light steel lever in a horizontal position. Each lever is provided with a steel point similar to those on the bars, and is so pivoted to the bar as to allow a limited vertical movement of the point.

As shown in the dotted lines in the sketch, one lever is of the first and one of the third order, so that a slight vertical movement of the points will raise the outer end of one lever and depress that of the other through a greatly magnified distance. To the outer end of one lever is attached a graduated scale, over which the pointed end of the second lever moves, showing the stretch of the specimen.

The instrument is so proportioned and the scale so graduated that ten-thousandths of an inch may be readily distinguished.

The scale stands out in front of the machine directly opposite the eye of the operator, where it is easily read.

Several months of practical use have shown this instrument to be as convenient and as accurate as many higher-priced extensometers.



STRENGTH OF BRIDGE AND TRESTLE TIMBERS.*

Your committee appointed to report on "Strength of Bridge and Trestle Timbers, with special reference to Southern Yellow Pine, White Pine, Fir and Oak," desires to present herewith, as part of their report, the very valuable data, compiled by the chairman of the committee, relative to tests of the principal American bridge and trestle timbers and the recommendations of the leading authorities on the subject of strength of timber during the last twenty-five years embodied in the appendix to this report and tabulated for easy reference in the accompanying tables.

The uncertainty of our knowledge relative to the strength of timber is clearly demonstrated after a perusal of this information, and emphasizes, better than long dissertations on the subject, the necessity for more extensive, thorough, and reliable series of tests, conducted on a truly scientific basis, approximating as nearly as possible actual conditions encountered in practice.

The wide range of values recommended by the various recognized authorities is to be regretted, especially so when undue influence has been attributed by them in their deductions to isolated tests of small-sized specimens, not only limited in number, but especially defective in not having noted and recorded properly the exact species of each specimen tested, its origin, condition, quality, degree of seasoning, method of testing, etc.

The fact has been proved beyond dispute that small size specimen tests give much larger average results than full size tests, owing to the greater freedom of small selected test pieces from blemishes and imperfections and their being, as a rule, comparatively drier and better seasoned than full-sized sticks. The exact increase, as shown by tests and by statements of different authorities, is from 10 to over 100 per cent.

Great credit is due to such investigators and experimenters as Professors G. Lanza, J. B. Johnson, H. T. Bovey, C. B. Wing, and Messrs. Onward Bates, W. H. Finley, C. B. Talbot, and others, for their experimental work and agitation in favor of full size tests. Professors G. Lanza, R. H. Thurston, and Wm. H. Burr have contributed valuable treatises on the subject of strength of timber. The extensive series of small and full size United States government tests, conducted in 1880 to 1882, at the Watertown Arsenal, under Colonel T. T. S. Laidley, and more recently the very elaborate and thorough timber tests being conducted by the United States Forestry Division, under Dr. B. E. Fernow, Chief, Professor J. B. Johnson, of Washington University, St. Louis, afford us to-day, in connection with the work of the above-mentioned experimenters, our most reliable data from a practical standpoint.

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* From a report of a committee of the American Association of Railway Superintendents of Bridges and Buildings.

The test data at hand and the summary criticisms of leading authorities seem to indicate the general correctness of the following conclusions:

1. Of all structural materials used for bridges and trestles timber is the most variable as to the properties and strength of different pieces classed as belonging to the same species, hence it is impossible to establish close and reliable limits of the strength for each species.

2. The various names applied to one and the same species in different parts of the country lead to great confusion in classifying or applying results of tests.

3. Variations in strength are generally directly proportional to the density or weight of timber.

4. As a rule, a reduction of moisture is accompanied by an increase in strength; in other words, seasoned lumber is stronger than green lumber.

5. Structures should be, in general, designed for the strength of green or moderately seasoned lumber of average quality and not for a high grade of well-seasoned material.

6. Age or use do not destroy the strength of timber, unless decay or season checking takes place.

7. Timber, unlike materials of a more homogeneous nature, as iron and steel, has no well defined limit of elasticity. As a rule, it can be strained very near to the breaking point without serious injury, which accounts for the continuous use of many timber structures with the material strained far beyond the usually accepted safe limits. On the other hand, sudden and frequently inexplicable failures of individual sticks at very low limits are liable to occur.

8. Knots, even when sound and tight, are one of the most objectionable features of timber, both for beams and struts. The full size tests of every experimenter have demonstrated not only that beams break at knots, but that invariably timber struts will fail at a knot, or owing to the proximity of a knot, by reducing the effective

area of the stick and causing curly and cross-grained fibres, thus exploding the old practical view that sound and tight knots are not detrimental to timber in compression.

9. Excepting in top logs of a tree or very small and young timber, the heart wood is, as a rule, not as strong as the material farther away from the heart. This becomes more generally apparent, in practice, in large sticks with considerable heart wood cut from the old trees in which the heart has begun to decay or been wind-shaken. Beams cut from such material frequently season check along middle of beam and fail by longitudinal shearing.

10. Top logs are not as strong as butt logs, provided the latter have sound timber.

11. The results of compression tests are more uniform and vary less for one species of timber than any other kind of test; hence, if only one kind of test can be made, it would seem that a compressive test will furnish the most reliable comparative results.

12. Long timber columns generally fail by lateral deflection or "buckling" when the length exceeds twenty diameters. In practice the unit stress for all columns for over fifteen diameters should be reduced in accordance with the various rules and formulæ established for long columns.

13. Uneven end bearings and eccentric loading of columns produce more serious disturbances than is usually assumed.

14. The test of full size long compound columns, composed of several sticks bolted and fastened together at intervals, show essentially the same ultimate unit resistance for the compound column as each compound stick would have, if considered as a column by itself.

15. More attention should be given in practice to the proper proportioning of bearing areas; in other words, to the compressive bearing resistance of timber with and across grain, especially the latter, owing to the tendency of an excessive crushing stress across grain to indent the timber, thereby destroying the fibre and increasing the liability to speedy decay, especially when exposed to the weather and the continual working produced by moving loads.

The aim of your committee has been to examine the conflicting test data at hand, attributing the proper degree of importance to the various results and recommendations, and then to establish a set of units that can be accepted as fair average values, as far as known to-day, for the ordinary quality of each species of timber and corresponding to the usual conditions and sizes of timber encountered in practice. The difficulties of executing such a task successfully cannot be overrated, owing to the meagerness and frequently the indefiniteness of the available test data, and especially the great range of physical properties in different sticks of the same general species, not only due to the locality where it is grown, but also to the condition of the timber as regards the percentage of moisture, degree of seasoning, physical characteristics, grain, texture, proportion of hard and soft fibres, presence of knots, etc., all of which affect the question of strength.

Your committee recommends, upon the basis of the test data at hand at the present time, the average units for the ultimate breaking stresses of the principal timbers used in bridge and trestle constructions shown in the accompanying table.

In addition to the units given in the table, attention should be called to the latest formulæ for long timber columns, mentioned more particularly in the appendix to this report, which formulæ are based upon the results of the more recent full size timber column tests and hence should be considered more valuable than the older formulæ derived from a limited number of small size tests.

Attention should also be called to the necessity of examining the resistance of the beam to longitudinal shearing along the neutral axis, as beams under transverse loading frequently fail by longitudinal of shearing in place transverse rupture.

In addition to the ultimate breaking unit stress the designer of a timber structure has to establish the safe allowable unit stress for the species of timber to be used This will vary for each particular class of structures and individual conditions. The selection of the proper "factor of safety" is largely a question of personal judgment and experience, and offers the best opportunity for the display of analytical and practical ability on the part of the designer. It is difficult to give specific rules. The following are some of the controlling questions to be considered:

The class of structure, whether temporary or permanent, and the nature of the loading, whether dead or live. If live, then whether the application of the load is accompanied by severe dynamic shocks and pounding of the structure. Whether the assumed loading for calculations is the absolute maximum rarely to be applied in practice or a possibility that may frequently take place. Prolonged heavy steady loading and also alternate tensile and compressive stresses in the same piece will call for lower averages. Information as to whether the assumed breaking stresses are based on full size or small size tests or only on interpolated values, averaged from tests of similar species of timber, is valuable in order to attribute the proper degree of importance to recommended average values. The class of timber to be used and its condition and quality. Finally the particular kind of strain the stick is to be subjected to, and its position in the structure with regard to its importance and the possible damage that might be caused by its failure.

In order to present something definite on this subject, your committee presents the accompanying table, showing the average safe allowable working unit stresses for the principal bridge and trestle timbers, prepared to meet the average conditions existing in railroad timber structures, the units being based upon the ultimate breaking unit stresses recommended by your committee, and the following factors of safety:

Tension, with and across grain,	10
Compression, with grain,	5
Compression across grain,	4
Transverse rupture, extreme fibre stress,	6
Transverse rupture, modulus of elasticity,	2
Shearing, with and across grain,	4

In conclusion your committee desires to emphasize the importance and great value to the railroad companies of the country of the experimental work on the strength of American timbers, being conducted by the forestry division of the United States department of agriculture, and to suggest that the American Association of Railway Superintendents of Bridges and Buildings indorse the view by official action and lend its aid in every way possible to encourage the vigorous continuance of this series of government tests, which bids fair to become the most reliable and useful work on the subject of strength of American timbers ever undertaken. With additional and reliable information on this subject, far-reaching economies in the designing of timber structures can be introduced, resulting not only in a great pecuniary saving to the railroad companies, but also offering a partial check to the enormous consumption of timber and the gradual diminution of our structural timber supply.

Your committee recommends upon the basis of the test data at hand at the present time, the average units for the ultimate breaking stresses of the principal timbers used in bridge and trestle constructions shown in the accompanying tables.

AVERAGE SAFE ALLOWABLE WORKING UNIT STRESSES IN POUNDS PER SQUARE INCH—RECOMMENDED BY COMMITTEE ON "STRENGTH OF BRIDGE AND TRESTLE TIMBERS."—AMERICAN ASSOCIATION OF RAILWAY SUPERINTENDENTS BRIDGES AND BUILDINGS.—FIFTH ANNUAL CONVENTION, NEW ORLEANS, OCTOBER 5, 1895.

Kind of Timber.	Tension.		Compression.			Transverse Rupture.		Shearing.	
	With Grain.	Across Grain.	With Grain.		Across Grain.	Extreme Fibre Stress.	Modulus of Elasticity.	With Grain.	Across Grain.
			End Bearing.	Columns under 15 Diams.					
Factor of Safety.	Ten.	Ten.	Five.	Five.	Four.	Six	Two.	Four.	Four.
White Oak,	1,000	200	1,400	900	500	1,000	550,000	200	1,000
White Pine,	700	50	1,100	700	200	700	500,000	100	500
Southern, Long Leaf, or Georgia Yellow Pine,	1,200	60	1,600	1,000	350	1,200	850,000	150	1,250
Douglas, Oregon and Washington Fir or Pine, Yellow Fir,	1,200	. . .	1,600	1,200	300	1,100	700,000	150	. . .
Red Fir,	1,000	. . .	. . .	. . .	. . .	800	. . . .	. . .	. . .
Northern, or Short Leaf Yellow Pine,	900	50	1,200	800	250	1,000	600,000	100	1,000
Red Pine.	900	50	1,200	800	200	800	600,000	. . .	. . .
Norway Pine,	800	. . .	1,200	800	200	700	600,000	. . .	. . .
Canadian (Ottawa) White Pine,	1,000	. . .	. .	1,000	. . .	. . .	. . . .	100	. . .
Canadian (Ontario) Red Pine,	1,000	. . .	. . .	1,000	. . .	800	700,000	100	. . .
Spruce and Eastern Fir,	800	50	1,200	800	200	700	600,000	100	750
Hemlock,	600	. . .	. . .	800	150	600	450,000	100	600
Cypress,	600	. . .	1,200	800	200	800	450,000	. . .	. . .
Cedar,	800	. . .	1,200	800	200	800	350,000	. . .	400
Chestnut,	900	. . .	. . .	1,000	250	800	500,000	150	400
California Redwood,	700	. . .	. . .	800	200	750	350,000	100	. . .
California Spruce,	. .	. . .	. . .	800	. . .	800	600,000	. . .	. . .

AVERAGE ULTIMATE BREAKING UNIT STRESSES IN POUNDS PER SQUARE INCH.—RECOMMENDED BY THE COMMITTEE ON "STRENGTH OF BRIDGE AND TRESTLE TIMBERS."—AMERICAN ASSOCIATION OF RAILWAY SUPERINTENDENTS BRIDGES AND BUILDINGS.—FIFTH ANNUAL CONVENTION, NEW ORLEANS, OCTOBER, 1895.

Kind of Timber.	Tension.		Compression.			Transverse Rupture.		Shearing.	
			With Grain.						
	With Grain.	Across Grain.	End Bearing.	Columns under 15 Diams.	Across Grain.	Extreme Fibre Stress.	Modulus of Elasticity.	With Grain.	Across Grain.
White Oak,	10,000	2,000	7,000	4,500	2,000	6,000	1,100,000	800	4,000
White Pine,	7,000	500	5,500	3.500	800	4,000	1,000,000	400	2,000
Southern, Long Leaf, or Georgia Yellow Pine,	12,000	600	8,000	5,000	1,400	7,000	1,700,000	600	5,000
Douglas, Oregon and Washington Fir or Pine, Yellow Fir,	12,000	. . .	8,000	6,000	1,200	6,500	1,400,000	600	. . .
Red Fir,	10,000	. . .	. . .	. . .	. . .	5,000	. . . .	. . .	. . .
Northern, or Short Leaf Yellow Pine,	9,000	500	6,000	4,000	1,000	6,000	1,200,000	400	4,000
Red Pine,	9,000	500	6,000	4,000	800	5,000	1,200,000	. . .	. . .
Norway Pine,	8,000	. . .	6,000	4,000	800	4,000	1,200,000	. . .	. . .
Canadian (Ottawa) White Pine,	10,000	. . .	. . .	5,000	. . .	. . .	. . . .	350	. . .
Canadian (Ontario) Red Pine,	10,000	. . .	. . .	5,000	. . .	5,000	1,400,000	400	. . .
Spruce and Eastern Fir,	8,000	500	6,000	4,000	700	4,000	1,200,000	400	3,000
Hemlock,	6,000	. . .	. . .	4,000	600	3,500	900,000	350	2,500
Cypress,	6,000	. .	6,000	4,000	700	5,000	900,000	. . .	. . .
Cedar,	8,000	. . .	6,000	4,000	700	5,000	700,000	. . .	1,500
Chestnut,	9,000	. . .	. . .	5,000	900	5,000	1,000,000	600	1,500
California Redwood,	7,000	. . .	. . .	4,000	800	4,500	700,000	400	. . .
California Spruce,	. . .	. . .	. . .	4,000	. . .	5,000	1,200,090	. . .	. . .

STEEL MANUFACTURERS' ASSOCIATION STANDARD SPECIFICATIONS GOVERNING THE PHYSICAL PROPERTIES OF STRUCTURAL STEEL.

Process of Manufacture.—1. Steel may be made by either the open hearth or Bessemer process.

Test Pieces.—2. All tests and inspections shall be made at place of manufacture prior to shipment.

3. The tensile strength, limit of elasticity and ductility shall be be determined from a standard test piece cut from the finished material and planed, milled and turned parallel. The elongation shall be measured on an original length of 8 inches, except when the thickness of the finished material is five-sixteenths inch or less, in which case the elongation shall be measured in a length equal to sixteen times the thickness; and except in rounds of five-eighth inch or less in diameter, in which case the elongation shall be measured in a length equal to eight times the diameter of section tested. Two test pieces shall be taken from each melt or blow of finished material; one for tension and one for bending.

3*a*. Material which is to be used without annealing or further treatment is to be tested in the condition in which it comes from the rolls. When material is to be annealed or otherwise treated before use the specimen representing such material is to be similarly treated before testing.

4. Every finished piece of steel shall be stamped with the blow or melt number; and steel for pins shall have the blow or melt number stamped on the ends. Rivet and lacing steel and small pieces for pin plates and stiffeners may be shipped in bundles securely wired together with the blow or melt number on a metal tag attached.

Finish.—5. Finished bars must be free from injurious seams, flaws or cracks and have a workmanlike finish.

Grade of Steel.—6. Steel shall be of three grades—rivet, soft, and medium.

Rivet Steel.—7. Ultimate strength, 48,000 to 58,000 pounds per square inch. Elastic limit, not less than one-half the ultimate. Elongation, 26 per cent. Bending test, 180 degrees flat on itself without fracture on outside of bent portion.

Soft Steel.—8. Ultimate strength, 52,000 to 62,000 pounds per square inch. Elastic limit, not less than one-half the ultimate. Elongation, 25 per cent. Bending test, 180 degrees flat on itself without fracture on outside of bent portion.

Medium Steel.—9. Ultimate strength, 60,000 to 70,000 pounds per square inch. Elastic limit, not less than one-half the ultimate. Elongation, 22 per cent. Bending test, 180 degrees to a diameter equal to thickness of piece tested without fracture on outside of bent portion.

Pin Steel.—10. Pins made from either of the above-mentioned grades of steel shall, on specimen test pieces cut at a depth of one inch from surface of finished material, fill the physical requirements of the grade of steel from which it is rolled for ultimate strength, elastic limit, and bending; but the required elongation shall be increased five per cent.

11. Eye-bar material, one and one half inches and less in thickness, made of either of the above-mentioned grades of steel, shall, on test pieces cut from finished material, fill the physical requirements of the grade of steel from which they are rolled. For thickness greater than one and one-half inches there will be allowed a reduction in the percentage of elongation of one per cent. for each one-eighth increase of thickness to a minimum of twenty per cent. for medium steel and twenty-two per cent. for soft steel.

Full Size Test of Steel Eye-Bars.—12. Full size test of steel eye-bars shall be required to show not less than ten per cent. elongation in the body of the bar, and tensile strength not more than 5,000 pounds below the minimum strength required in specimen tests of the grade of steel from which it is rolled.

The bars will be required to break in the body, but should a bar break in the head but develop ten per cent. elongation and the ultimate strength specified, it shall not be cause for rejection, provided not more than one-third of the total number of bars tested break in the head; otherwise the entire lot will be rejected.

Variations in Weight.—13. The variations in cross-section or weight of more than two and one-half per cent. from that specified will be sufficient cause for rejection, except in the case of sheared plates ordered to gauge, in which event there will be permitted an excess of weight over that corresponding to the dimensions on the order equal in amount to that specified in the following table:

TABLE OF ALLOWANCE FOR OVERWEIGHT FOR RECTANGULAR PLATES.

	Up to 75 inches wide. Per cent.	75 to 100 inches wide. Per cent.
For plates ¼ inch wide,	10	14
For plates 5-16 inch wide,	8	12
For plates ⅜ inch wide,	7	10
For plates 7-16 inch wide,	6	8
For plates ½ inch wide,	5	7
For plates 9-16 inch wide,	4½	6½
For plates ⅝ inch wide,	4	6
For plates over ⅝ inch wide,	3½	5

Specifications for Structural Cast Iron.—1. Except where chilled iron is specified, all castings shall be tough gray iron, free from injurious cold shuts or blow holes, true to pattern, and of a workmanlike finish. Sample pieces one inch square, cast from the same heat of metal in sand molds, shall be capable of containing on a clear span of four feet eight inches a central load of 500 pounds when tested in the rough bar.

MANUFACTURERS' STANDARD SPECIFICATIONS GOVERNING THE PHYSICAL PROPERTIES OF SPECIAL OPEN HEARTH PLATE AND RIVET STEEL.

Test Pieces.—1. All tests and inspection shall be made at place of manufacture prior to shipment.

2. The tensile strength limit of elasticity and ductility shall be determined from a standard test piece cut from the finished material and planed, milled or turned parallel. The elongation shall be measured on an original length of eight inches, except when the thickness of the finished material is five-sixteenths of an inch or less, in which case the elongation shall be measured in a length equal to sixteen times the thickness; and except in rounds of five-eighths of an inch or less diameter, the elongation shall be measured in a length equal to eight times the diameter of section tested. Four test pieces shall be taken from each melt of finished material; two for tension and two for bending.

2*a*. Material which is to be used without annealing or further treatment is to be tested in the condition in which it comes from the rolls. When material is to be annealed or otherwise treated before use the specimen representing such material is to be similarly treated before testing.

3. Every finished piece of steel shall be stamped with the melt number. Rivet steel may be shipped in bundles securely wired together with the melt number on a metal tag attached.

GRADES OF STEEL.

Extra Soft Steel.—4. Ultimate strength, 45,000 to 55,000 pounds per square inch. Elastic limit, not less than one-half the ultimate strength. Elongation, twenty-eight per cent. Cold and quench bends, 180 degrees flat on itself without fracture on outside of bent portion.

Fire Box Steel.—5. Ultimate strength, 52,000 or 62,000 pounds per square inch. Elastic limit, not less than one-half the ultimate strength. Elongation, twenty-six per cent. Cold and quench bends, 180 degrees flat on itself without fracture on outside of bent portion.

Flange or Boiler Steel.—6. Ultimate strength, 52,000 to 62,000 pounds per square inch. Elastic limit, not less than one-half the ultimate strength. Elongation, twenty-five per cent. Cold and quench bends, 180 degrees flat on itself without fracture on outside of bent portion.

Boiler Rivet Steel.—7. Steel for boiler rivets shall be of the extra soft qualities specified in paragraph No. 4.

TABLE OF ALLOWANCE FOR OVERWEIGHT FOR RECTANGULAR PLATES.

	Up to 75 inches wide. Per cent.	75 to 100 inches wide. Per cent.
For plates ¼ inch thick,	10	14
For plates 5-16 inch thick,	8	12
For plates ⅜ inch thick,	7	10
For plates 7-16 inch thick,	6	8
For plates ½ inch thick,	5	7
For plates 9-16 inch thick,	4½	6½
For plates ⅝ inch thick,	4	6
For plates over ⅝ inch thick,	3½	5

For all plates ordered to gauge there will be permitted an excess of weight over that corresponding to the dimensions on the order equal in amount to that specified in the above table.

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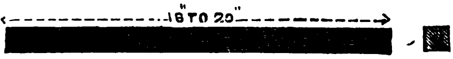
Form of Specimen for Tensile Tests of Wrought and Cast Iron, Steel and Alloys.

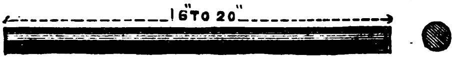
The specimens to be tested must not be over three inches wide, and of the shapes illustrated below, and up to 4 ft. long. The sectional area must not be of such proportions as to require a greater strain than 200,000 pounds to break them.

No. 1.



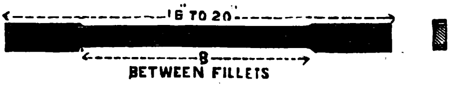
Square or flat bar, as rolled.

No. 2.



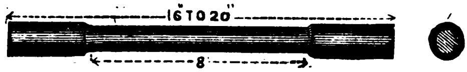
Round bar, as rolled.

No. 3.



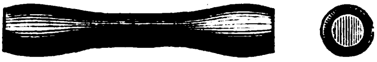
U. S. Government and American Society Civil Engineers' standard shape for specimen cut from plate. Ends must not be over three inches wide.

No. 4.



American Society Civil Engineers' standard shape for square or round, turned down in middle.

No. 5.



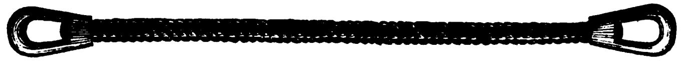
Standard shape for cast iron. Reduced section, 1 inch area.

Form of Specimen for Tensile Tests of Chain, Rope, Etc.

No. 6. Chain.

Any length from 18 in. to 4 ft., measuring inside of shackles. The outside measurement of shackles must be 3 in. x 4 in. or less, viz.: so as to go through a hole 3 in. x 4 in. large.

No. 7. Wire Rope.



Any length from 18 in. to 4 ft., measuring inside of loops. The outside measurement of end loops must be 3 in x 4 in., viz.: so as to go through a hole 3 in. x 4 in. large.

No. 8. Hemp Rope.

Any length from 18 in. to 4 ft., measuring inside of loops. The outside measurement of end loops must be 3 in. x 4 in. or less, viz.: so as to go through a hole 3 in. x 4 in. large.

Tensile Tests can be made up to four feet in length, and **Transverse Tests** up to five feet. Transverse specimens of cast iron are made: 1 in. square, 14 ins. long, for 12-in. tests; 1 in. square, 26 ins. long, for 24 in. tests; 1 in. square (or 1 x 2 ins.), 52 ins. long, for 48-in. tests; 1 in. square (or 1 x 2 ins.), 58 ins. long, for 54-in. tests. Greater lengths can be tested, but for these special quotations must be made.

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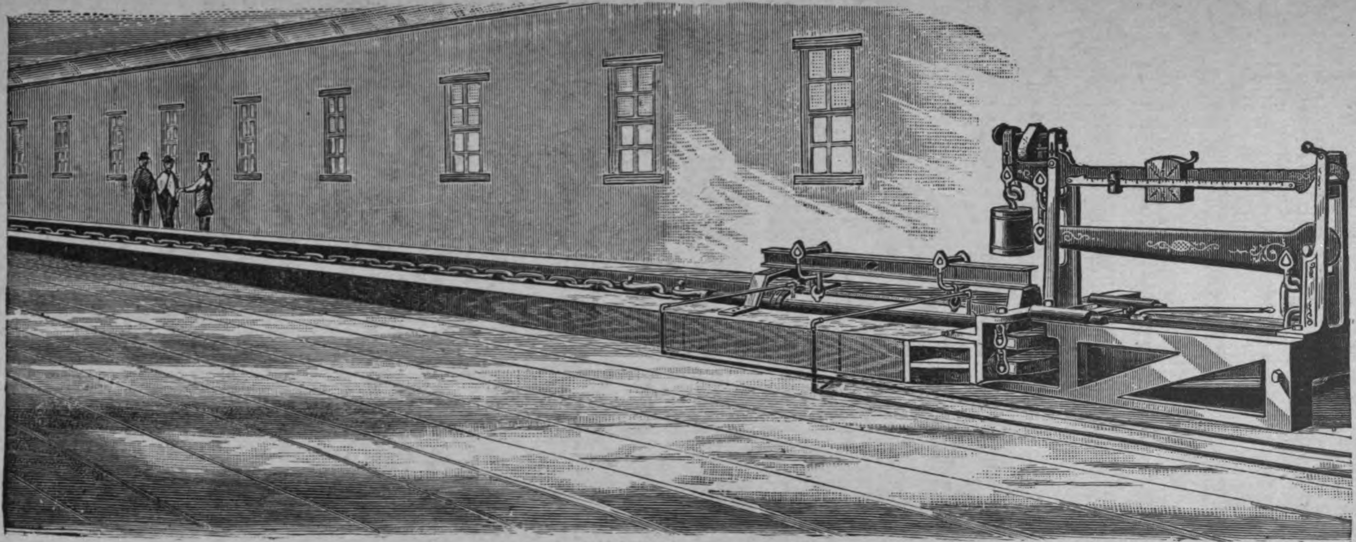

PLATE No. 22.

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Vol. I. APRIL, 1896. No. 2.

The Digest
OF
Physical Tests
AND
Laboratory Practice.

A résumé of Practical Tests made in the Laboratories of the World.

EDITED BY H. M. NORRIS.

PUBLISHED QUARTERLY
BY
FREDERICK A. RIEHLÉ,
1424 North Ninth Street, Philadelphia, Pa., U. S. A.

Telegraphic address from all parts of the world, "RIEHLÉ PHILADELPHIA."

Entered, according to Act of Congress, in the year 1895, by FREDERICK A. RIEHLÉ,
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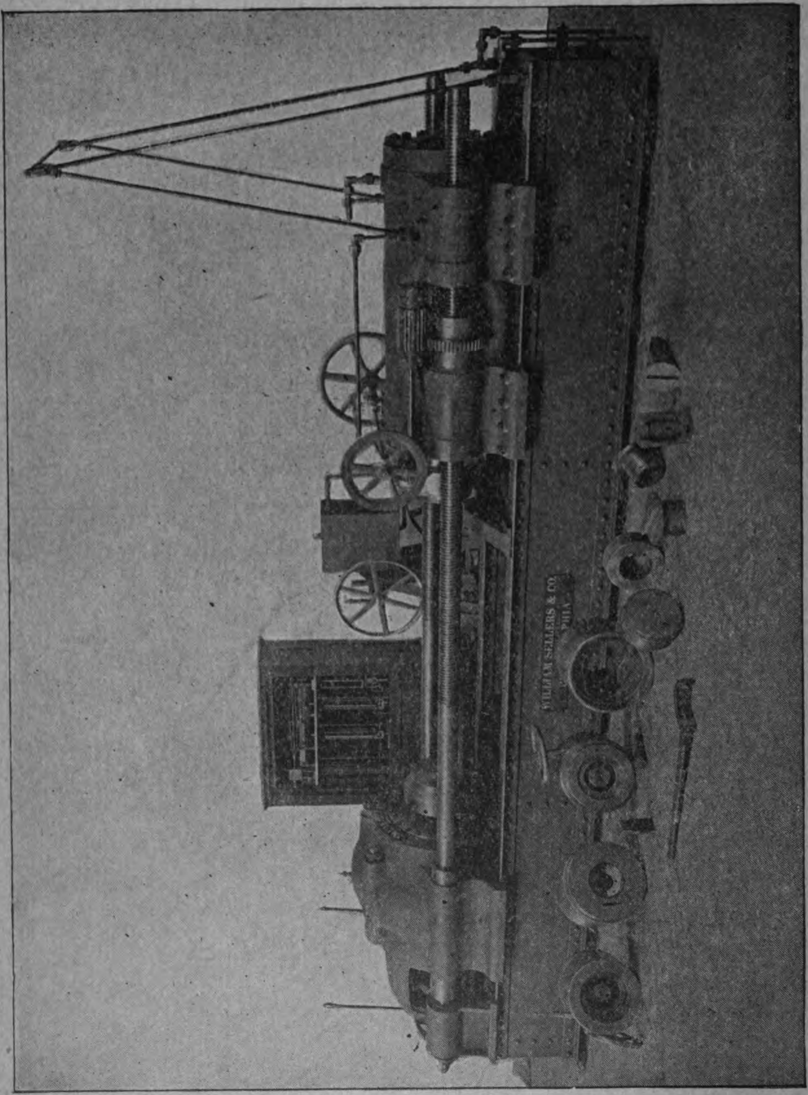

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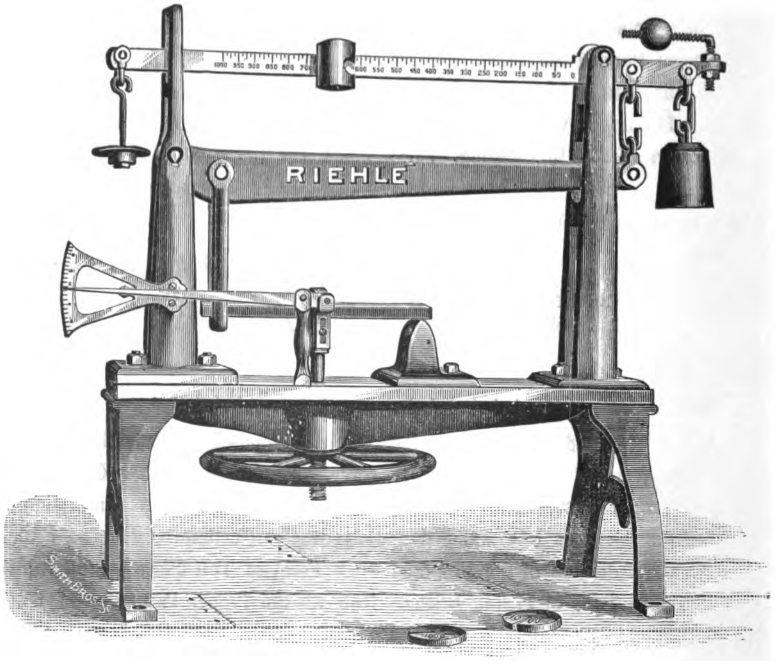

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Digest of Physical Tests.

A RÉSUMÉ OF PRACTICAL TESTS MADE IN THE
LABORATORIES OF THE WORLD.

Vol. I. **APRIL, 1896.** **No. 2.**

SCIENTIFIC TIMBER TESTING.

By B. E. Fernow, Chief of Division of Forestry, Department of Agriculture.

IT is a remarkable fact that although wood has been, through all ages, and continues to be the most widely used building material, less definite knowledge is to be found regarding its behavior, its strength, and the factors which influence these than regarding any other material. Timber testing, to be sure, has been carried on as long as any testing of materials, but the results of such testing have mostly remained unsatisfactory, because the testing was not carried on by scientific methods.

There are two reasons for this deficiency: While all other materials are more or less homogeneous, being manufactured by man, and capable, therefore, of being produced under nearly uniform and known conditions, and with nearly uniform results, wood, the product of nature, is most non-homogeneous, and being produced under constantly varying conditions, a result of many changing seasons, it is most variable in its structure, quality, and behavior. In fact, while we may say that with materials like iron, brick, cement, and even stone, we test the material, with wood we test a complicated structure of ever-varying design. While the difficulty, therefore, of arriving at satisfactory data for general application is great, the other reason for our deficiency in them comes from the fact that most of the testing done in the past has been done by engineers who were not at the same time botanists, or rather physiologists, and who failed to study and to appreciate, or to allow for the variability of this fickle material. Not only is it necessary to distinguish between the many different species—engineers are rarely capable of recognizing more than the genus, if one may judge from the engineers' tables of strength, in which mostly generic names only, spruce, fir, pine, oak, etc., are used—but one must know also to distinguish differences in development of the species, and take into consideration physical as well as chemical properties of wood.

I would make, therefore, this first postulate for the successful timber-tester, that he be not only an engineer but a botanist at the same time, or else have a botanist, a man conversant with vegetable physiology, at his elbow. There are not even many botanists who know enough of the physical properties and the behavior of wood to be able to fill the position. To be a successful tester of timber, the rare combination of engineer, botanist, and physicist, an expert in "timber physics," is required.

Although Muschenbroek and Buffon and Duhamel de Monceau, in the last century, carried on timber tests with some regard to the various influences upon strength, coming apparently to contradictory results, while Barlow and Dupin, early in this century, Poncelet, Hodgkinson, Paccinoti, and Peri later did good service in working out experimentally the mathematical side, the first time that such a combination of naturalist and technicist was nearly attained, was when the two Frenchmen, Chevandier and Wertheim, the one an engineer, the other a forester, undertook in the fifth decade to subject the timbers of France to a comprehensive investigation, with due regard to proper rules of inspection of the test material, publishing their results in 1848. But although many valuable truths were established by these men and those following their methods, among their number Tetmayer and Bauschinger, the highest authorities on timber testing at present, the subject has not by any means been exhausted, and when it comes to American timbers we can, without invidiousness, say that none of the tests that have been made until very recently were carried on with the precautions and inspection of the material that make them conclusive or practically applicable.

WHAT ARE TESTS MADE FOR?

There are two objects to be subserved in testing of any kind of materials, and we may divide the testing accordingly into two classes. The one, which we may call *commercial* testing, has in view to find out the relative value for a given purpose, of a given lot of materials offered in market or presently to be applied; it does not inquire into the properties in general, their variations due to different causes, or into the reasons for such variation. The other kind of testing, which we may call *scientific* testing, has in view to find out what the capabilities of materials are, what causes the properties, how they are related to each other, and how they may be produced or influenced; it attempts to develop *laws* of strength and to furnish data for *general* application.

The first kind of testing simply records the *usage* of the practice, the second lays the foundation for the *improvement* of the practice. From a lot of iron or steel to be used in a bridge some sample pieces are broken, to assure the engineer that the rest of the lot is capable of sustaining a given load: this is commercial testing, the result of which is simply to state that the present lot of iron is of a given quality in the average, satisfactory for our present purpose, but it does not allow us to judge from this to another lot of iron, manufactured elsewhere under different conditions. In fact, unless we are sure that all the material was made and treated alike, and that the samples represented it fairly, we know hardly more than what we learned of the sample pieces themselves.

From the same lot the manufacturer takes samples, tests them for their strength, and examines them carefully as to structure and chemical analysis, the appearance of the fracture, the behavior during the test, and considers these data, together with the manner in which he had produced this material, and perhaps compares all these data with similar data obtained from another lot of material. This is scientific testing, which furnishes us a general judgment as to the qualities of the material under varying conditions and appearances, and leads, for the practitioner, to *rules of inspection* and to improved methods of manufacture or application.

So well is it understood that commercial testing is an insufficient assurance of the quality of a lot of iron or steel that in important work, bridge construction, for instance, inspectors are constantly present during the manufacture of the material to assure themselves that the stipulated ingredients enter into the material, and that it receives a stipulated treatment; and no engineers' tables are considered satisfactory by themselves. Yet there has been developed for this class of materials a tolerably reliable set of rules for inspection, so that by physical examination an approximation to the quality and behavior of the material can be diagnosed. Not so for timber. Most tests that have been carried on in our mechanical laboratories have been done in this wise: Material has been secured from a wood-yard under the name given by the yard-man, who notoriously mixes various species together and cannot distinguish them; no attempt is made to make sure of the species; in fact, the means for doing so are usually not at the command of the professor; no knowledge as to the conditions under which the material has grown exists, or from what part of the tree it comes; no knowledge as to how it has been treated after felling; no careful examination as to the moisture it contains, although this factor alone, it is known, influences strength to an extent of sometimes more than 50 per cent.; no examination as to its position in the tree with reference to the grain, nor of the character of its structure, its specific gravity. In short, the whole performance is more or less blind.

From what has been said regarding the great variability of wood, we may at once discard the idea that our knowledge will be increased appreciably by a continuance of the methods of breaking sticks, large or small, indiscriminately, without knowledge as to what they really are. Commercial testing, as we have called it, may satisfy the consumer in a special case, but it does not furnish general knowledge; it does not permit of general application with any degree of reliability. In fact, commercial testing with so variable material as wood is hardly of use until we have also data of inspection, derived from systematic series of tests, which allow us to compare the tested material with that of which the test piece was supposed to be a sample, and to gauge how far the sample represents the average, or how far above or below the quality of the untested material may fall; in other words, until scientific testing enables us to interpret its results. Nay, I may go so far as to say that when by a systematic series of wood testing data for inspection have been established, commercial testing will become unnecessary, the mere inspection of the material furnishing much more reliable results.

For such data of inspection we must have recourse to what we have called scientific testing, which consists in a methodical, systematic procedure, planned with circumspection and carried out consistently on testing material selected with careful reference to all conditions that may have an effect on its quality and behavior. Scientific experiment in general consists in analyzing first the variables which contribute toward a complex total effect, and then by eliminating as many as possible of the variables determine the effect of any one or of any one set of variables in various combinations. They are designed not to show what the practitioner is doing, but to explain the phenomena in the practice and thereby to improve the practice.

The first requisite of course is that we should know what the material is we are testing. This seems axiomatic, and yet, as we have stated before, most experimenters have known but imperfectly the nature of their specimens. If, for instance, we wish to establish the value of the species known as Longleaf Pine, we must make sure that it is Longleaf Pine which we are testing. This cannot be done by selecting from a wood-yard, for we have so far not even any means of distinguishing its wood with certainty, and other species are easily mixed in, hence we must have the material selected in the woods by a botanist who by foliage and fruit can make sure that the tree belongs to the species sought.

As a matter of more indirect interest rather than for rules of inspection, it is desirable to note the exact conditions of soil, climate, and surroundings, such as may influence the quality of the tree, and the part of the tree from which the test material is taken. For this knowledge may give us an indication as to what to expect from given growth conditions, and assist us later in selecting for different purposes the various cuts, which may differ by fully 25 per cent. in their strength.

The next point to observe is the treatment of the material after felling: the manner in which the seasoning is done. Due to the non-homogeneous arrangement of the various parts of the log or stick, the contraction due to the loss of water from the cell walls, which make up the wood structure, is uneven, and gives rise to "season checks" invariably. These are always by necessity sources of weakness, even though closing up again, by swelling due to water absorption or re-arrangement of parts. This variable is impossible to eliminate, and so difficult to take into account that all the experimenter may do is to reduce its occurrence to the smallest extent possible by careful attention to the seasoning process.

The next care is in the shaping of the test stick. This is usually done by sawing and with little reference to resulting relations of the structural aggregates which make up the stick. In the first place, the fact that most trees do not lay on their annual growth in straight up-and-down arrangement of cell elements, but form a more or less spiral growth, which if cut with reference to the direction of the mathematical axis results in cross-grain of varying degree, points to the necessity of splitting the wood, which gives more assurance of reducing this variable. If sawing is adhered to, the existence of cross-grained condition must at least not be lost sight of in interpreting results. In the next place, attention must be paid to the lay of the annual rings with reference to the cut. The tree being built up by a series of superimposed hollow cones or rather neloid-shaped bodies of wood, a cut parallel to the axis produces sticks containing different sets of structural aggregates according to the location of the cut with reference to the radical plane, as will be readily understood by reference to the figure.* In each case the combination of structural aggregates, cones and cone sections, varies and gives rise to difference in strength of the combination; hence whether the stick is cut quarter-sawed or rift-sawed, or bastard-sawed, makes all the difference in its behavior.

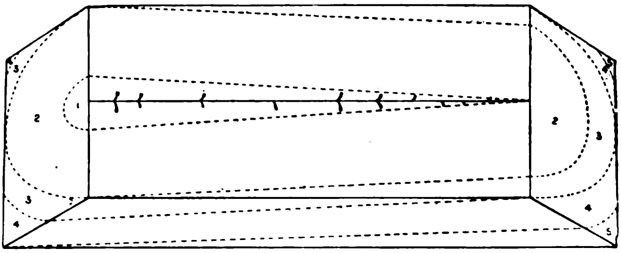

FIG. 1.—A piece of sawn timber cut through along the pith, illustrating its structural aggregates.

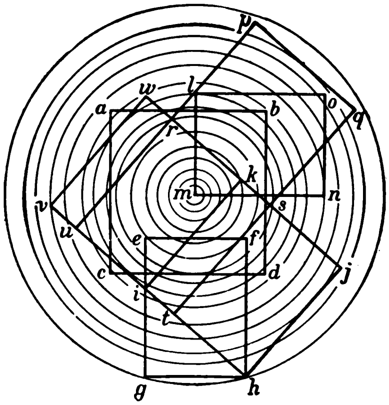

FIG. 2.—Possibilities of cutting timber from a log with reference to position of grain.

Having now secured a test stick with knowledge of its species, its derivation, its position in the tree, and its structural aggregates, at least three further facts must be ascertained —the character of its growth, its moisture contents, and its specific weight. In the species which have a distinct ring growth, like the pines, oaks, etc., in which each ring contains two classes of wood—namely, springwood and summerwood, the one loose or porous, the other made up of dense, thick-walled cells—the proportion of each of these predicates the strength and the weight of the seasoned wood is naturally also predicated by the proportion of these two elements of the annual ring. This feature alone—not the width of the ring, but the proportion of the summerwood and springwood forming the ring—is perhaps the most reliable criterion for an inspection and qualitative determination of the material.

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* Kindly loaned by the U. S. Department of Agriculture.

One of the most difficult of all the variables to take care of and yet one of the most important and the most variable one is the moisture contents. Often more than half the weight of freshly-felled timber is due to water, which is partly contained in the cell lumina, partly in the cell walls. In seasoning this water is lost; at first, while the lumen furnishes the supply for the evaporation readily, then more and more slowly, and such is the hygroscopicity of wood that it never parts with all the water, but retains, varying with the temperature and moisture conditions of the atmosphere in which it is kept, from eight to twelve and more per cent. From the point when the cell wall begins to lose water, which for pine, for instance, may be roughly placed at 35 per cent. of the weight of the dry wood, with the loss of water the strength is increasing rapidly, so that the same stick may show when dried to 10 per cent. a strength 50 per cent. greater than in the unseasoned condition. It is therefore of greatest importance to know the moisture per cent. of the test piece and the rate of variation with the loss of water.

The methods for ascertaining the moisture per cent. so far employed are still unsatisfactory, especially when it is considered that the moisture is not evenly distributed through the stick; the determination by borings practiced by Bauschinger, and even the disk method employed in the Division of Forestry do not quite satisfy the requirements of desirable exactitude; hardly anything short of repeated weighings and drying of the test piece itself will be reliable.

That all pieces containing knots and other defects must be excluded from a series which is to establish the standard value of the species—except when the effect of such defects is to be tested—seems self-evident. We may also take for granted as an essential requisite true workmanship in shaping the test piece. Lastly, the position of the grain, with reference to the load in the test, is an essential point that must not be forgotten, for according to this relation of load to structure different values will be obtained, a matter in which wood differs from iron or steel.

Finally, a word as to the size of the test pieces: Practical engineers have clamored for tests on large sizes such as are used in practice, claiming that tests on small selected pieces do not give data applicable in practice. This is an erroneous position, provided the tests which are to furnish the standard are made in large number, and with such precaution, and under such rules of inspection as stated, whereby the data become applicable to any case. It is true that larger sizes are apt to behave differently, although not always and not necessarily, from smaller sizes for good reasons; but even Prof. Lauza, who has attempted to establish the numerical difference in the value of tests on large and small sizes has failed to explain the cause of the difference fully, and failed especially to give us such data regarding his test material as will allow us to inspect the material and apply his coefficients to any other material than that tested.

In large timbers not only is the chance for defects increased, but the variables above referred to become more complex and less controllable, while the relation of structural aggregates, as explained before, allows of greatest variety; especially the degree of seasoning, varying greatly in their various parts, withdraws itself from control. They are, therefore, not fit for the purpose of establishing reliable standard data, for such only select material of quality and condition, as thoroughly known as possible, is permissible, and of sizes which, while large enough to secure a sufficiently high per cent. of accuracy, avoid as much as possible the difficulties mentioned in regard to defects, cross grain, uneven seasoning, etc. It then becomes the subject of special investigation to determine the effect of each of the variables, and, finally, it may be desirable to investigate directly the effect of their combination as found in large sizes by analysis of the tested columns and beams themselves.

I hear some "practical" engineer say that in practice it would be impossible to apply such refined knowledge, and hence the test data should refer to conditions only which occur or are usual and recognizable in actual practice.

To such my answer can here only be brief. This paper is not written for them; they need some instruction in the history and philosophy of scientific work as applied to practical results, when they will learn that progress, improvement of the practice, can be expected only from applying the opposite of their practical methods. The more refined, the more careful and systematic the methods by which a scientific investigation is carried on, the more likely will it produce results useful to the practice. The conditions, which in the scientific work we analyze and take separate account of, occur in the practice in ever-varying combination. As in chemical and electrical arts, the skillful practitioner must and will learn to disintegrate them, and with the aid of the data furnished by scientific standards make the necessary allowances.

The Division of Forestry has entered upon a series of tests and investigations in timber physics carried on with the precautions outlined for the purpose of determining not only more thoroughly the range of values for our various species but especially of determining the effect of the variables affecting strength and furnishing rules of inspection. The work has progressed slowly on account of deficient funds. During the last four years, however, over 30,000 tests have been made with thorough examination of the test material, and at least for the four Southern pines the data based on over 18,000 tests are already well established.

SYSTEMATIC INSPECTION OF MATERIAL.

By L. S. Randolph, Professor of Mechanical Engineering, Virginia Agricultural and Mechanical College, Blacksburg, Va.

IT would seem that it ought to be completely superfluous to tell a man that it was advisable for him to know what he was buying, or that it would pay him to ascertain whether or not he was getting full value for his money. It will require but a very superficial observation, however, to show that the contrary is the case, and that it will be necessary not only to tell him, but in many cases the most convincing arguments will be ineffectual.

The facility with which all classes of nostrums are foisted on the community, and the difficulty of obtaining reliable material go to show that very few realize the necessity of knowing when the material they buy is what it should be.

No more valuable move has been made, of recent years, by our railroads, then a recognition of the fact that it was necessary to know accurately the character of the material they were using, both in track and rolling stock; so that at the present time all first-class roads either have a testing bureau, as a special department of their own organization, or employ one of the numerous testing bureaus.

The fact that the leading engineers have, for years, required careful and systematic tests of material on all important work, that on the Continent testing bureaus have been established under governmental supervision, and the number of independent testing bureaus in this country, proves the practical necessity for the systematic examination and testing of the materials of construction.

This demand comes from two quarters: 1st. The necessity of protecting human beings from injury or death. 2d. The necessity, especially at the present time, for practicing the utmost economy.

It is scarcely necessary to discuss, or to advance arguments, to prove the necessity for taking every precaution, to prevent the injury or death of a human being. Whilst this has been treated as an economic problem more than once, that phase need scarcely be discussed here, for its value as a factor in the design of any structure will depend entirely upon the moral condition of those in charge of the work.

The value of systematic testing, from an economic standpoint, however, is open to fuller discussion, and brings up more interesting questions.

In conversation with an engineer the other day on this subject, he told me that he was satisfied that he had been compelled, recently, to use from 15 to 20 per cent. more material in a building than was necessary, on account of the impossibility of having the material carefully tested, and this in face of the fact that especially good prices had been paid for it. The saving on a few such buildings would have equipped a testing laboratory.

In a recent investigation of the strength of cements, a sample of cement, which sold for $5 per barrel, when mixed with one-half sand, showed a greater tensile strength than did a sample of another cement selling for $3.50 per barrel, when used neat; and yet enormous quantities of this cheap cement are used.

The author has again and again seen lubricants sold to private consumers, under some high-sounding name, at from 50 to 75 cents a gallon, which were nothing but plain petroleum products, worth, probably, at the most, 20 cents per gallon. One cannot blame an oil salesman for taking advantage of such a snap, but it is rather hard on the man who foots the bills. A considerable portion of the lubricants sold to small consumers are not worth one-half what is paid for them. In fact, it may be taken as a rule that in every branch of trade more or less chicanery and fraud are deliberately practiced, the only safeguard against which is the careful examination of the material.

But it will be argued that one can deal with honest manufacturers only. While it is unquestionably good policy to have no dealings whatever with dishonest parties, yet this does not remedy the matter.

A manufacturer or dealer may be as honest as possible, but that does not prevent his employees from making mistakes, or from willfully shipping defective material to cover their own errors. We might, perhaps, locate dishonest dealers, but it would be impossible to locate the ignorant, careless, or dishonest employee.

The amount of material with defects, which it is inconceivable that any sane person could fail to see, which is shipped by the most reputable concerns proves that the honesty of the head of a concern does not insure the honesty of his subordinates, although it may go a long way toward it.

We have, therefore, to avoid not only the dishonesty of the manufacturers, but also the dishonesty and carelessness and ignorance of their subordinates.

In a steel mill a forging may be piped; if carefully plugged, the chances are that nothing will be heard of it until the failure of the forging reveals the hidden flaw; too late, however, to trace it back and place the responsibility where it belongs.

It has been held, and by the majority, believed, that it is necessary to have inspected and tested the materials used on only the more important structures, such as bridges, office buildings, etc., where there is danger to life or limb of the occupants. While it is undeniably true that such material should be inspected, it is also true that, as a rule, greater economies can be effected by inspecting other kinds of materials, where the results of the failure are not so dangerous to human life and consequently not so disastrous to the reputation of the manufacturer.

The very fact that in most instances the other kinds of material are purchased without any examination at all, gives an invitation to all kinds of fraudulent practices. There is an extensive trade in certain materials, which are used for adulteration alone.

In an investigation, made by the writer of different brands of white lead, only two out of six samples were found to be worthy of the name of white lead; three being utterly worthless.

Upon one occasion, a shipment of lard oil received by the writer was found to contain a large portion of paraffine oil; it was returned, and a second shipment replacing it was also returned for the same cause. At last a shipment of oil was received which was satisfactory. When asked why they shipped such defective material, the reply was that they did not expect it to be so rigidly inspected.

That the rigid examination of materials, which are now received without inspection, is desirable, can scarcely be denied, but how far it should be carried and to what extent it would be economical, is another and a more difficult question to solve. It is evident that it would be advisable, if practical, to have everything tested and inspected; but throwing aside this utopian idea, we can readily see that the systematic inspection of material can be extended far beyond its present limited sphere, with very beneficial results.

As an illustration of what can be done by such inspection, we can find no better example than the results obtained from the inspection of fertilizers. At one time fertilizers were sold entirely on the makers' guarantee or statement; now, in nearly all States some system of fertilizer control is in force, whereby all fertilizers sold in the State, are subject to inspection and analysis, and in some States any citizen can send a sample of fertilizer to the State Chemist, have it analyzed, and an estimate of its value, per ton, placed upon it.

The result of this system of fertilizer control has been not only a marked improvement in the value of the fertilizer actually sold, but, what is of far more importance, the introduction of a condition of affairs which renders the sale of worthless fertilizers practically impossible.

Similar benefits can unquestionably be obtained from an extension of this system to other materials, such as iron, steel, cast iron, oils, paints, and soaps. At present it is very difficult to get a paint which is worth anything, or a good lubricating oil at a reasonable price, and many of the soaps sold throughout the country are so injurious to clothes as to be worse than useless. Is this not, after all, a matter for governmental control? It may be claimed that this is too much like paternalism, but it is unquestionably the duty of the Government to detect and punish fraud wherever found, and there is considerable room here for the exercise of this function. Have not all classes as much right for protection against fraud as the Agricultural, if that class would not be the principal beneficiaries of government inspection?

A NEW TRANSMISSION DYNAMOMETER.

By S. W. Robinson, Professor of Mechanical Engineering, Ohio State University.

IN designing and equipping a machine shop, or, in fact, a manufacturing establishment of any kind, one of the first problems met with, as touching economy and efficiency, is the amount of power required to run the plant. In olden times when the teeth of gear wheels were chipped and filed, and engine cylinders were bored by pushing a hand tool along a plank, this expense was either boldly guessed at, or roughly estimated according to the number of men employed, one horse-power, for instance, being considered sufficient to drive a suitable number of machine tools to keep ten men at work. In modern times, however, where every possible leakage must be looked to with the greatest care, it is not only desirable, but absolutely essential to the welfare of the concern that an accurate knowledge should be had of the amount of power developed by the motor, and the amount required to drive each machine.

The only satisfactory method of ascertaining these quantities is by the use of some form of dynamometer—by which we mean an instrument or machine for measuring the power exerted by an engine or electro-motor, or the amount of power consumed in driving a single machine or machinery plant. A Dynamometer is primarily an instrument to measure the work done by an effort of some kind, the result being usually expressed in *foot-pounds* and given in a lump sum, as 10,000, meaning ten thousand foot-pounds : as in the case of the Integrating Dynamometer. But more frequently the result is a diagram area as by the Recording Dynamometer, which area, when measured by duly considering the co-ordinates and determining the area, represents the foot-pounds. Thus the steam engine *indicator* is, in one sense, a recording dynamometer, because the pressure ordinates of the indicator diagram multiplied by the stroke abscissas, gives an area which represents the foot-pounds of work performed by the engine for the corresponding stroke of that engine.

Sometimes the pressure or force ordinates only are indicated by the instrument, the space ordinates, or abscissas, being determined by some other means than by the so-called dynamometer. Thus the work done in drawing a plow along a furrow may be measured by observing at frequent equal intervals a spring dynamometer applied between the plow and whiffletree, while the distance, or space passed over by the plow at the same time, is measured by a tape line or similar means. Then, multiplying the mean tractile force, in pounds, given by the spring dynamometer, by the space in feet will give the foot-pounds of work which was required for turning the furrow by the plow and team, the entire work, friction and all, being measured. An ordinary spring balance for weighing may thus be used for a dynamometer, from which it would seem that this instrument is named according to the service required of it, as spring balance, dynamometer, etc. Dynamometers are divided into two classes, viz.: *Absorption Dynamometers* and *Transmission Dynamometers;* the former being especially adapted to the measurement of the power developed by motors, by absorbing or neutralizing it, usually by friction, but not applicable for measuring the power required to drive a lathe or grinding-mill; while the second, or Transmission Dynamometer, is especially adapted for determining the amount of power necessary to drive a machine by measuring it while being transmitted to the machine. The Transmission Dynamometer may, however, be used also for ascertaining the power of motors, the instrument being applied near the motor and transmitting all its power.

According to Morin, the sensibility of a dynamometer should be proportional to the intensity of effects to be measured, and should not be liable to alterations by use. The indications of flexures should be obtained by methods independent of the attendance, fancies, or prepossessions of the observer, and should consequently be furnished by the instrument itself, by means of tracings, or material results, remaining after the experiments. The observer should be able to ascertain the effort exerted at each point of the path described by the point of application of the effort, or, in certain cases, at each instant in the period of observations. If the experiment from its nature must be continued a long time, the apparatus should be such as can easily determine the total quantity of work expended by the motor.

To meet these conditions various instruments have been designed by Morin, Webber, Briggs, Tatham, Brackett, Hartig, and others, all of which are sufficiently accurate for all practical purposes. But, in addition to possessing accuracy, and the other qualifications already mentioned, a dynamometer should be simple in construction, light for transportation, quick in adaptation, easy to read, and the results such as can be rapidly converted into the horse-power transmitted, and above all, the machine sufficiently cheap to be within reach of every manufacturer.

To this end, after a fruitless search in the market for a truly desirable instrument, the Transmission Dynamometer, illustrated in Fig. 1, was designed and built by the writer for the Testing Laboratory of the Ohio State University, where it has done admirable service. This machine consists essentially of a supporting frame, or pedestal, a T-shaped arm carrying the driving mechanism, and a graduated scale or weighing apparatus.

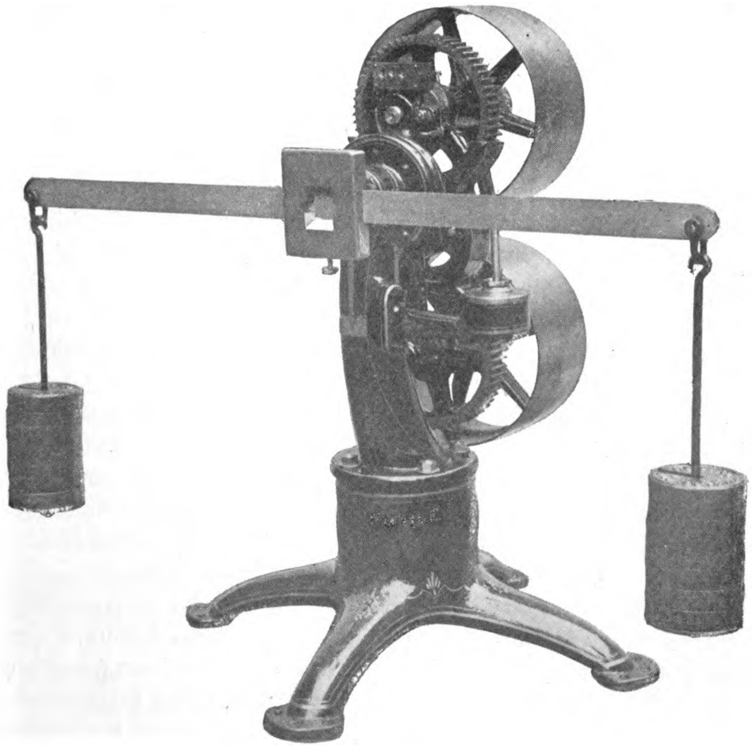


FIG. 1.

To use the instrument it is made fast to the floor with the pulleys under or to one side, but in the plane of the belt which drives the machine, the power to drive which is to be measured. Then with the machine set as shown in the illustration the lower pulley of the dynamometer is connected with the machine, while a second belt connects the pulley on the instrument with the pulley on the power shaft. This arrangement of pulleys enables the observer to connect his instrument without moving either the machine to be measured, or the driver on the main line.

The two pulleys of the instrument are mounted on a strong cross-tree bar so that they both overhang and can be swung around to any position. This overhang and swing makes it convenient to put either belt on or off without unlacing, and to swing the pulleys either way for tightening or loosening both belts. We may say, as a rule, both belts, for in setting the instrument up we can so set it, both as to location on the floor and position of cross-tree bearing, that by swinging the cross-tree one way we tighten *both*, or the other way loosen *both* belts. This movement of the cross-tree is made possible, and even convenient, by the cylinder and flange connection to the head of the column, the latter having screws and slots covering the full circle, so that the cross-tree may be set free to turn, and again made fast in any desired position. Thus the two pulleys may be swung about to any position in the whole circle to suit the particular location in hand. In swinging the pulleys and cross-tree thus, the set screw, making fast the poise bar, should be slackened and again tightened when the desired position is found. Thus the driving belt may come down from above, from the one side, or from below to its proper pulley on the short arm of the cross-tree; while the pulley on the longer arm is to be connected to the machine to be measured, the cross-tree being first set, if desired, so that both belts are loosened or tightened simultaneously, due regard being paid to the poise-bar set screw.

Sometimes it may be desired to slacken up for conveniently laying off the belts, as well as to tighten them. This feature of perfect adaptation for tightening or loosening the belts has been found a most useful one in practice with this dynamometer, as the belts can always be given the necessary tightness without going beyond the most suitable conditions.

The pulleys have each a gear on the end of the hub, both of which mesh into a smaller gear between, the latter being supported on a pin made fast as a crank pin in the arm from a shaft which passes through the centre of the hub of the cross-tree in the head of the main column. To the opposite end of this shaft the poise bar is made fast by a set screw in a boss to which the poise bar is secured. Thus when the small intermediate gear is thrust to the one side or the other by the large gears, the poise bar is correspondingly moved.

It will now be readily understood that as work is transmitted from one pulley to the other through the intermediate gear on the crank pin, the latter will be thrust to one side with a force proportioned to the effort transmitted, and that the same will tend to tip the poise bar, to prevent which weights are applied. It is plain that the equilibrating weights on the poise bar of a duly calibrated instrument together with speed, etc., furnish data for calculation of the work being transmitted.

The poise bar is graduated and has a sliding weight, called poise weight, to move from one end to the other, and the graduations count from o at the middle to 10 at either end. At each end of the bar is a knife-edge pin to which is suspended a rod and foot plate, or pan, that may carry fourteen or less weights of five ℔s. each. Every weight is marked "5 ℔s.=100 ft. ℔s. per rev. as shifted from pan to pan."

In starting an experiment, the fourteen weights, or less if preferred, may be equally divided between the opposite ends of the poise bar, and the poise weight may be in the middle of the poise bar, when the latter is in equilibrium, or balanced. Now the poise weight is moved out more and more on the poise bar till the end is reached if not sooner equipoised by the work being transmitted. Then the poise weight is brought back to the centre, and one 5-℔. weight at the same time moved over from one poise pan to the other, the same making a difference of 10 ℔s. and just equal to the 10 of the poise weight moved from end to centre. Then the poise weight is moved out more and more again till the end figure 10 is again reached, if not sooner equilibriated, when it is again moved back and another 5-℔. weight moved over, and so on. Finally an equilibrium is found as between the poise bar at one end and the gears at the other end of the crank shaft. Then a count of the weight will tell the number of pounds that acted to turn the poise bar; the poise weight being perhaps at 6, and the 5-℔. weights perhaps adding up to 30, as if 3 weights were moved over from one side to the other. It is to be observed that each 5-℔. weight moved over counts 10 in the equipoise, as by taking 5 off of one side and putting it on the other making 10 in effect.

The three weights moved over then count 30 pounds and the poise weight counts 6 pounds, making 36 pounds in all. The work being transmitted is therefore 360 foot-pounds per revolution, the number of pounds being multiplied by ten to give the foot-pounds per revolution.

Another way to count is to keep track of the number of weights moved over, each counting 100 foot-pounds. Then the three weights and the six on the poise bar make in effect 3.6 weights or 360 foot-pounds per revolution.

The tables are added to illustrate the calibration and the reduction of observations made with the instrument.

TABLE I.

Giving corrections for readings taken from the Transmission Dynamometer in use at the Ohio State University.

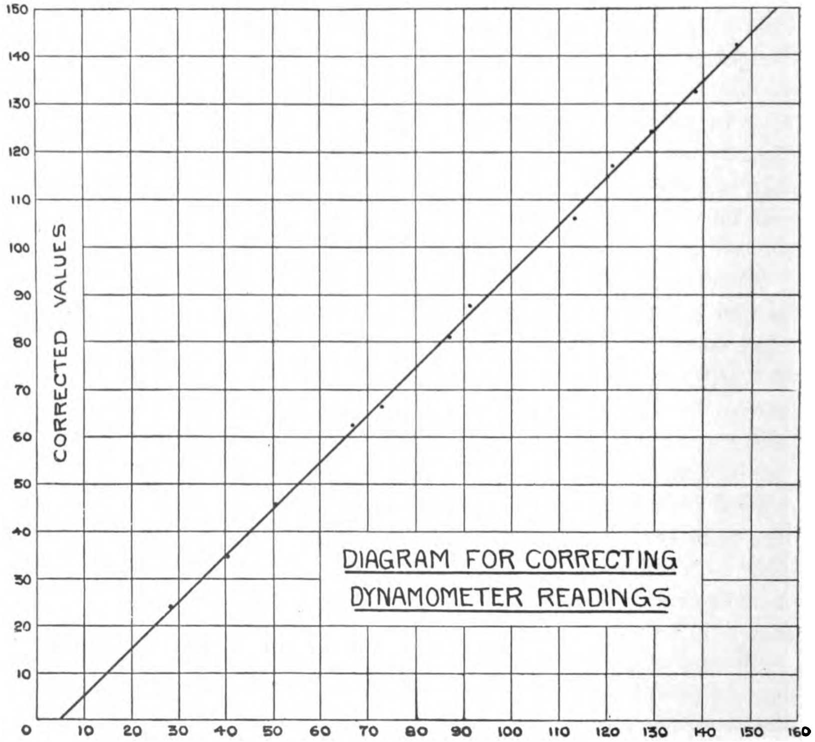


Table I shows that readings from the instrument mentioned are very readily corrected, it simply requiring five to be deducted.

The diagram also shows that the various results of observation plot very near to a straight line lying at an angle of 45°, there being a close agreement between the various observations. Each new instrument should have a correcting diagram of some kind made out for itself, as the law of each instrument may differ from that of another.

Table II is an example of results of observations for determining the horse-power required to drive a ventilating fan of about 5 feet diameter.

TABLE II.

POWER REQUIRED TO DRIVE A VENTILATING FAN.

SIZE OF FAN ORIFICE.	DYNAMOMETER READINGS.	CORRECTED DYN. READINGS, FT. LBS. PER REV.	REVOLUTIONS PER MINUTE.	H. P. TO RUN FAN.
1 foot	310 0	305.0	336	3.11
2 feet	285.3	280.3	432	3.70
3 feet	259.3	254.3	444	3.40
4 feet	127.6	122.6	328	1,22
4 feet	214.5	209.5	450	2.86
4 feet	224.5	319.5	440	2.93
4 feet	256.0	251.0	460	3.50
4 feet	254.1	248.1	490	3.68

The figures in the column of readings are the means of several readings, and hence the decimals.

The corrected readings are obtained from the Table I above for correcting the readings of this instrument which gave these results. The Table I shows that 5 is to be subtracted, simply from each reading, thus explaining the difference between columns 2 and 3. Hence in column 3 we have the foot-pounds per revolution of dynamometer pulley. Before correcting, we have, as readings, the figure 310, which means that three of the 5-pound weights had been passed over from one scale pan to the other, making 300 foot-pounds per revolution while the poise bar read 1 or 10 foot-pounds per revolution, making 310 foot-pounds per revolution as uncorrected.

But other instruments may not always give readings, the correction for which will be 5 to subtract, but some figure to be determined by calibration, similarly as was done for Table I.

Among the advantages of this instrument may be mentioned its adaptation for receiving the belts from any direction as down from above, from one side, or up from below. In each case, the most advisable arrangement is to place the cross-tree, on which the pulleys are mounted, in such position that both belts will be tightened by swinging it in one direction, or loosened by swinging in the opposite direction, the belt to take the power force to the machine to be measured being that from the pulley on the longer arm of the cross-tree. Then the belts can be adjusted any time to be just at the desired tightness without relacing, and by simply swinging the cross-tree arm.

Formulas for the Dynamometer will be found useful in practice. To this end take

D=diameter of the belt pulley (driven pulley).
R=radius of gear on that pulley.
r=radius of the intermediate gear, and radius of crank arm.
l=half length of poise bar.
W=difference of weights on scale pans.
w=poise weight, "reduced" to scale pan.
F=difference of belt tensions on driven pulley.
T=tangential component of pressure between gear teeth.
f=pressure against crank pin.
n=number of revolutions of pulley per minute.
S=square ft. of belt per H. P. per minute.
u=width of belt on dynamometer pulley.

Then

$$f = 2\,T = 2\,F\frac{D}{2\,R} = \frac{F\,D}{R}$$

$$fr = (W + w)\,l = \frac{F\,Dr}{R}$$

$$\frac{\pi\,D\,n\,u}{S} = H\ P = \frac{F\,\pi\,D\,n}{33000}$$

or

$$\frac{F}{33000} = \frac{u}{S}$$

and

$$(W + w)\,l = \frac{Dr}{R} \cdot \frac{u}{S} \cdot 33000$$

In the 25 H. P. instrument at the Ohio State University Mechanical Testing Laboratory, D = 14 inches, R = 5 inches, r = $3\frac{1}{12}$ inches, l = 23.54 inches, and u = 6 inches.

Then, taking the highest value of n at 1,000, and solving for S, we have

$$S = \frac{\pi\,D\,n\,u}{H\,P} = \frac{3\frac{1}{7} \cdot \frac{14}{12}\ 1000 \cdot \frac{1}{2}}{25} = 73.3$$

giving 73.3 square feet of belt per minute passing over the pulley when the instrument is working to its highest capacity. This figure is more ample than the 60 determined by J. H. Cooper as a fair value some years ago.

The quantity of weights to accompany the instrument is

$$W + w = \frac{Dr}{I R} \frac{u}{S} 33000 = 82 \text{ lbs.}$$

as found by substituting and reducing.

Making the weights of 5 lbs. each and allowing 10 lbs. for the equivalent of the poise weight, we find we require a trifle over 14 weights, but propose 14 as the number to go with the instrument.

In this case 7 or less may be placed on each pan in starting an experiment, the poise weight being at the centre. This collection of weights on poise bar will serve as an efficient inertia damper to check jerky movements of the poise bar, and reduce demands upon the dash-pot.

Then, as above explained, proceed by moving the poise weight slowly out to the end of the graduation, 10, if not sooner balanced by the power transmitted. Then move the poise weight back to 0, and move over a 5-lb. weight from one pan to the other which amounts to 10 in effect, and equals the effect of the poise weight just returned to centre; then move the poise weight out again to 10 if not sooner balanced; then moving it back to 0 and transfer another 5-lb. weight from pan to pan, and so proceed till the balance is obtained between power and poise bar. Then count up the weights moved over, each being counted for 100 foot-pounds per revolution, allowing the same for the poise weight clear out, as already described in the previous example. If 4 weights were moved over, they would count 400 foot-pounds per revolution, and if the poise weight were clear out it would count 100, or 500 foot-pounds per revolution in all. Or if the poise weight were at 3.7 the count would be 437 foot-pounds per revolution, etc. If running at 100 revolutions per minute the H. P. transmitted would be

$$\frac{43700}{33000} = 1.324 \text{ H. P.}$$

PAVING BRICKS.

TESTED FOR COMPRESSIVE STRENGTH AND ABSORPTION (PER CENT.).

By F. Paul Anderson, M. E., Professor of Mechanical Engineering,
State College of Kentucky, Lexington, Ky.

THE following tables present the results of a series of tests on twenty different kinds of paving bricks to determine their compressive strengths and the per cent. of moisture absorbed.

A brick to be well adapted for street paving purposes must, first of all, have a good compressive strength.

Secondly, a paving brick must not be brittle, therefore its spalling point should be high.

Thirdly, a paving brick should not absorb more than 3.5 per cent. of moisture.

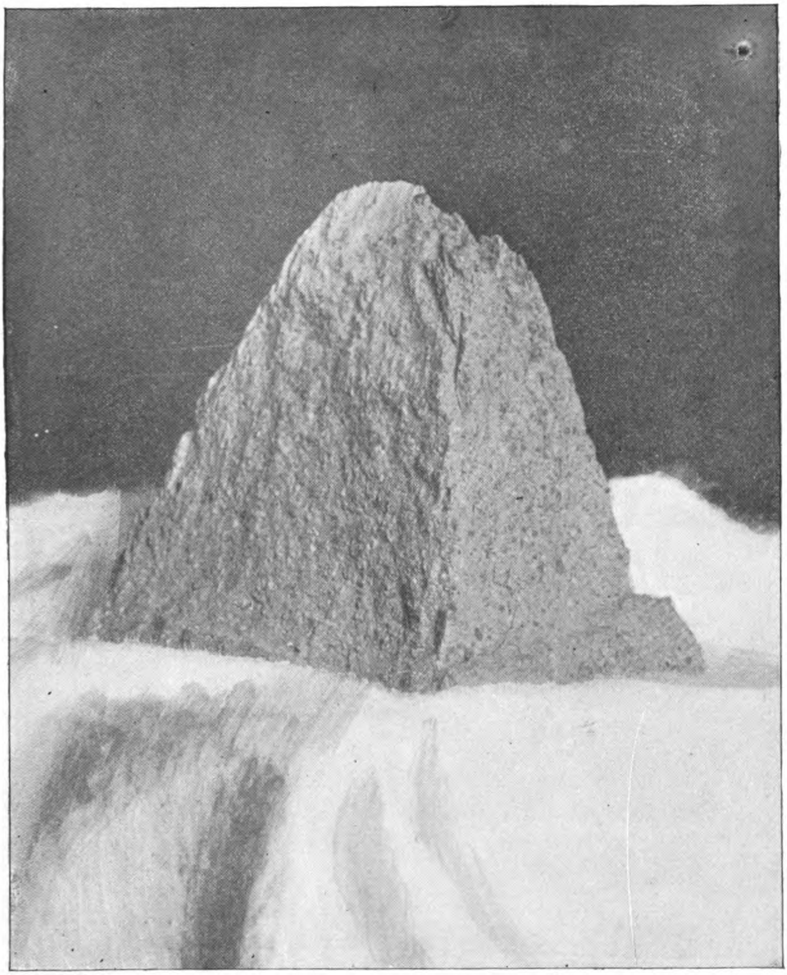
The last qualification is regarded, by some street-paving engineers, to be most important, for they contend that all bricks are practically strong enough to carry all loads put upon them, and that the tendency to disintegrate determines the life of a brick. The continued freezing and thawing of a brick full of water surely starts internal fractures.

The compressive tests of the bricks hereafter recorded were conducted with great care. The bricks were first cut in half by a skillful stone-cutter; their middle faces were ground parallel. A Riehlé 100,000 pound Screw Testing Machine was used in the work, and for several specimens the machine was loaded 25 per cent. above its capacity. The specimens were imbedded in plaster of Paris on the compression plates, the line of stress being coincident with the line of pressure in practice. (The bricks were crushed on edge.)

After each test, the machine was balanced to avoid any error.

The ordinary plan employed in the testing of bricks for absorption was not adopted in this case. The usual method is to cut the brick in half and put both halves in water for seventy-two hours, weighings being made before and after immersion.

This method I deem unscientific and unfair, as glazed and unglazed bricks surely would not be tested on the same basis.



FRACTURE OF A MACK FIRE CLAY BRICK.

The plan employed in the tests recorded was to cut from the interior of the bricks, avoiding all glazed surface, a block which was solid and free from cracks.

These blocks were dried and weighed on a chemical balance to within 1-500 of a grain, then immersed in water twenty-four hours and weighed again, giving the per cent. of moisture absorbed very accurately.

I also present photographs of fractures of sets of bricks, which indicate very clearly the homogeneous structure, comparatively, of the various types. On page 109 is shown a fracture of a Mack fire-clay brick, which approaches very nearly the pyramidal form.

On page 111 is shown the two pyramidal fractures of a Mack fire-clay block just as they stood in the machine after the final giving way of the specimen.

In some cases the number of specimens tested of each set, was not large, but included all we were able to secure.

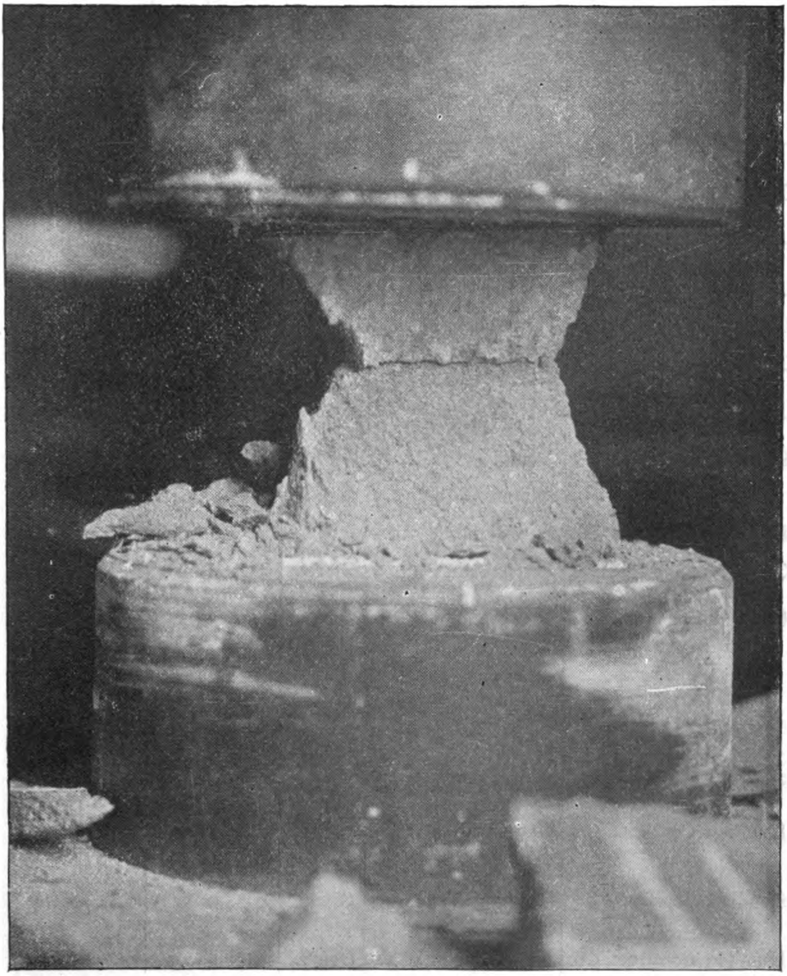
Most of the varieties in question contained over six specimens, therefore the average results are to be depended upon.

For a number of years some of the makers of paving bricks have contended that a paving brick should not absorb more than 2.5 per cent. of moisture, and in most of the cities specifications for street paving have specified that any brick absorbing more than 2.5 per cent. of moisture would be rejected.

Experience has proven that a first-class paving brick may absorb as much as 4 per cent. of moisture, and it has been unfortunate that makers of paving bricks, in order to comply with the 2.5 per cent. requirement, have gone to the other extreme, and are putting upon the market a brick almost impervious to water, but one extremely brittle and glassy.

When a paving brick becomes impervious to water we are bound to make the same so rigid and brittle that its pliability is lost, and therefore loses one of the most desirable features of a successful paving brick.

The record of tests for compressional strength and the amount of moisture absorbed, herewith presented, includes twelve of the most important and reliable paving bricks made in the country, and the illustrations of the fractures form an important feature, for by these fractures we are able to determine, to a large extent, the homogeneity of the paver, and by this means the care with which the material is ground and worked will be apparent.



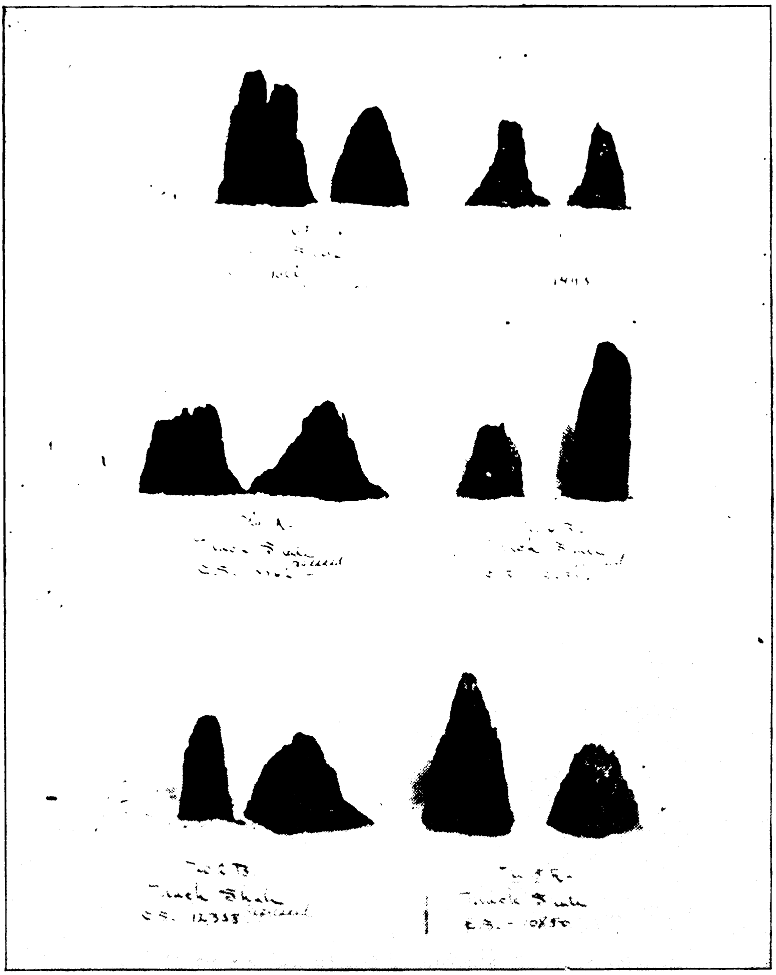
PYRAMIDAL FRACTURES OF A MACK FIRE CLAY BLOCK.

REPORT OF ABSORPTION TESTS OF

Company Submitting Specimen.	Locality.	Character of Surface of whole Brick.	Approximate Size of whole Brick in Inches.	Color.
Charles Spinks & Son, .	Portsmouth, Ohio,	Glazed,	9 x4 x3	Bluish brown,
P. Bannon, ...	Louisville, Ky., . .	Ungl'zd,	8½x4 x2½	Brownish red,
Grant R. B. Co., . . .	Middleport, Ohio, .	Glazed,	9 x4 x3	Dark brown,
Lyttle & Dolan, . . .	Philipsburg, Pa., .	Ungl'zd,	8½x4 x2½	Dark red, . .
Grant R. B. Co., . . .	Middleport, Ohio, .	Glazed,	8 x4 x2½	Bluish brown,
Charles Spinks & Son, .	" " .	"	9 x4 x3	Dark brown,
Lyttle & Dolan, . . .	Ironton, Ohio, . .	"	9 x4 x2½	"
" "	Canton, Ohio, . .	Ungl'zd,	8½x4 x2½	Brownish red,
Hunt'ton Construct. Co.,	New Cumb'ld, W.Va.	"	9 x4 x3	"
Charles Spinks & Son, .	Portsmouth, Ohio, .	Glazed,	9 x4 x3	Red'sh brown,
Hunt'ton Construct. Co.,	New Cumb'ld, W. Va.	Ungl'zd,	8 x4 x2½	Dark red, . .
" "	" "	"	8 x4 x2½	"
" "	" "	"	8 x4 x2½	Yel'ish brown,
Standard Construct. Co.,	Robbins, Tenn., .	"	8 x4 x2½	"
Hunt'ton Construct. Co.	New Cumb'ld, W.Va.	"	8½x4 x2½	"
Standard Construct. Co.	Robbins, Tenn., .	Glazed,	9 x4 x2½	Dark brown,
Hunt'ton Construct. Co.,	New Cumb'ld, W.Va.	Ungl'zd,	9¼x4 x3	Yel'ish brown,
Standard Construct. Co.,	Robbins, Tenn., .	"	9 x3¾x2½	"
" "	" " .	Glazed,	8½x4¼x2½	Dark brown,
Lexington Brick Co., .	Lexington, Ky., .	Ungl'zd,	8½x4 x2½	Dark red, . .

TWENTY KINDS OF PAVING BRICKS.

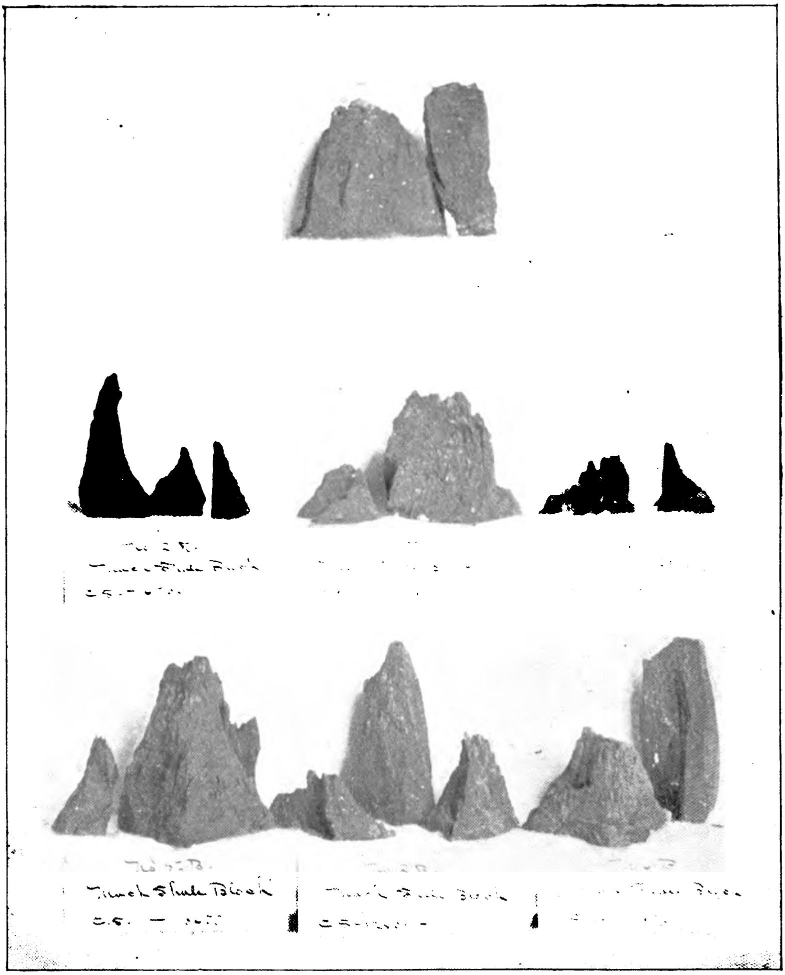
Label attached to Specimen.	Weight of Specimen in Grams when Dry.	Weight of Specimen in Grams after being Submerged in Water.	Gain in Weight in Grams.	Per Cent. of Gain in Weight.	Remarks.
Kentucky Block, . .	425.19	427.55	2.36	.55	Middle edges sharp. Two continuous grooves on largest and smallest faces.
Bannon Brick, . . .	211.42	213.14	1.72	.81	Smallest edges round.
McManigal, ...	287.81	291.85	4.04	1.4	
Monongahela Shale, .	262.79	266.84	4.05	1.54	Edges sharp.
Riverside Paver, . .	317.23	322.37	5.14	1.62	Three grooves on back.
Grant Block R. B. Co.,	312.85	318.02	5.17	1.65	Middle edges sharp. Three grooves on back.
Ironton F. B. C. Paver,	253.37	257.61	4.24	1.67	Edges sharp.
Canton Shale Paver,	343.01	349.97	6.96	2.02	Edges sharp.
Mack Shale Block, .	232.81	237.77	4.96	2.13	Middle edges sharp.
Charles Spinks & Son,	377.16	385.30	8.14	2.16	Two grooves on largest faces.
Mack Shale Re-pressed Brick, .	232.81	238.84	6.03	2.58	Middle edges sharp.
Mack Shale Standard A Square, .	455.12	468.06	12.94	2.84	Edges sharp.
Mack Fire Clay Re-pressed Brick,	236.09	242.85	6.76	2.86	Middle edges sharp.
Robbins Paver, . . .	187.27	193.25	5.98	3.19	Middle edges sharp.
Mack Fire Clay Standard A Square,	245.12	253.06	7.94	3.24	Shortest edges round.
Hallwood Block, . .	190.17	196.35	6.18	2.25	Middle edges sharp. Two continuous grooves on largest and smallest faces.
Mack Fire Clay Block,	366.73	379.25	12.52	3.41	
Hallwood Block, . .	176.61	183.46	6.85	3.87	Middle edges sharp. Two continuous grooves on longest and smallest faces.
Robbins Paver, . . .	240.85	251.13	10.28	4.27	Middle edges sharp.
Lexington Brick, . .	244.21	282.43	38.22	15.65	Edges sharp.



FRACTURES OF SETS OF FIRE BRICKS.

REPORT OF COMPRESSION TEST OF TWENTY KINDS OF PAVING BRICKS.

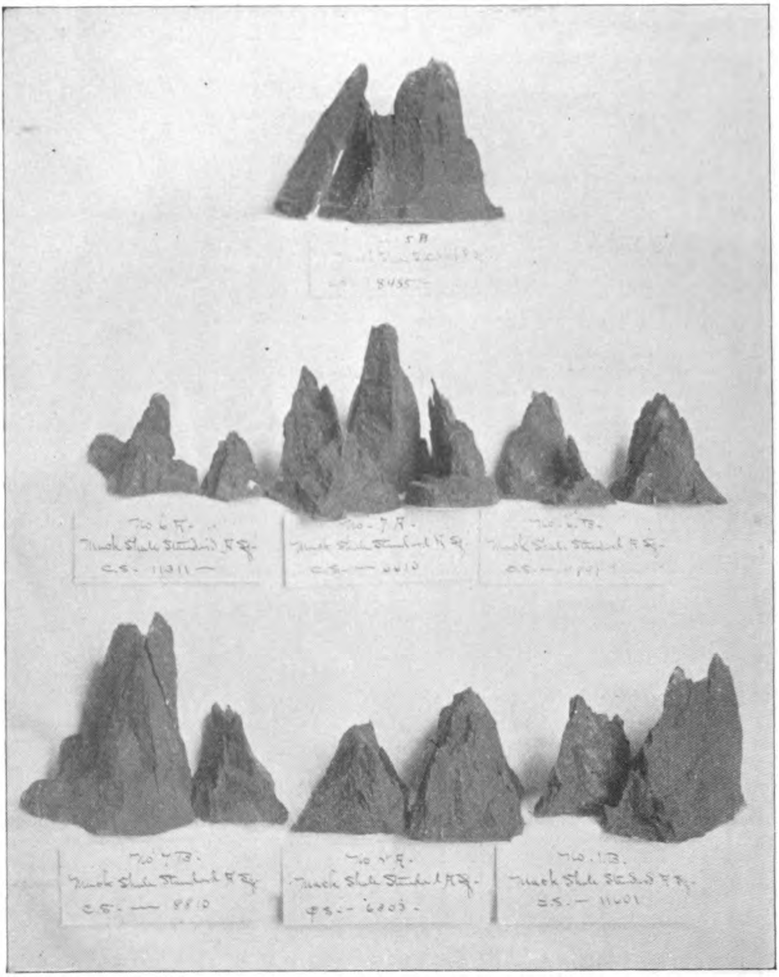
Company Submitting Specimen.	Locality.	Number of Specimens from which Average was Obtained	Character of Surface of whole Brick.	Approximate Size of whole of Brick in Inches.	Color.	Label attached to Specimen.	Load at which Specimen Began to Spall.—Pounds.	Crushing Strength per Square Inch.—Pounds.
Lyttle & Dolan, ...	Canton, Ohio, ...	2	Unglazed	8½x4 x2½	Dark red, . . .	Standard Canton Shale Paver, . . .	60,365	14,253
Huntington Construction Co.,	New Cumberland, W. Va.,	7	"	8 x4 x2½	" . . .	Mack Shale Re-pressed Brick, . . .	36,111	12,276
Lyttle & Dolan, ...	Philipsburg, Pa., ...	1	"	8½x4 x2½	" . . .	Monongahela Shale Paver, ...	66,600	10,342
Huntington Construction Co.,	New Cumberland, W. Va.,	9	"	8½x4 x2½	Yellowish brown,	Mack Fire Clay Standard A Square,	50,053	10,209
" "	" "	7	"	9 x4 x3	Dark red, . . .	Mack Shale Block, ...	28,990	9,870
" "	" "	7	"	8 x4 x2½	" . . .	Mack Shale Standard A Square, . .	35,775	8,997
Charles Spinks & Son, ...	Portsmouth, Ohio, . . .	6	Glazed,	9 x4 x3	Reddish brown,	Kentucky Block, ...	22,105	7,785
Huntington Construction Co.,	New Cumberland, W. Va ,	9	Unglazed,	8½x4 x2½	Yellowish brown,	Mack Fire Clay Re-pressed Brick, .	37,972	7,354
Charles Spinks & Son, ...	Portsmouth, Ohio, . . .	9	Glazed,	9 x4 x3	Reddish brown,	Charles Spinks & Son, ...	30,847	7,161
Lyttle & Dolan, ...	Ironton, Ohio, ...	7	Unglazed.	9 x4½x2½	Dark brown, . .	. . . .	18,617	6,663
Huntington Construction Co.,	New Cumberland, W. Va..	9	"	9 x4 x3	Yellowish brown,	Mack Fire Clay Block, ...	47,209	6,589
P. Bannon, ...	Louisville, Ky., ...	3	"	8½x4 x2½	Brownish red, .	Bannon Brick, ...	17,610	6,044
Standard Construction Co., .	Robbins, Tenn , ...	7	"	8½x4 x2½	Yellowish brown,	Robbins Paver, ...	26,030	5,815
" " .	" "	9	Glazed,	8½x4 x2½	Dark brown, . .	" "	20,421	4,784
" " .	" "	9	Unglazed,	9 x4 x2½	Yellowish brown.	Hallwood Block, ...	21,668	4,765
" " .	" "	9	Glazed,	9 x4 x2½	Bluish brown, .	" "	20,867	3,979
Lexington Brick Co., ...	Lexington, Ky , ...	9	Unglazed	8½x4 x2½	Dark red, . . .	Lexington Brick, ...	24,283	3,694
Grant R. B. Co., ...	Middleport, Ohio, ...	2	Glazed,	8 x4 x2½	Bluish brown, .	Grant R. B. Co., ...	12,165	3,398
Charles Spinks & Son, ...	" "	9	"	9 x4 x3	Dark brown, . .	Charles Spinks & Son, ...	14,932	3,265
Grant R. B. Co., ...	" "	2	"	9 x4 x3	" . .	McManigal, ...	10,038	2,747



FRACTURES OF SETS OF FIRE BRICKS.

DATA OF COMPRESSION TEST OF PAVING BRICKS.

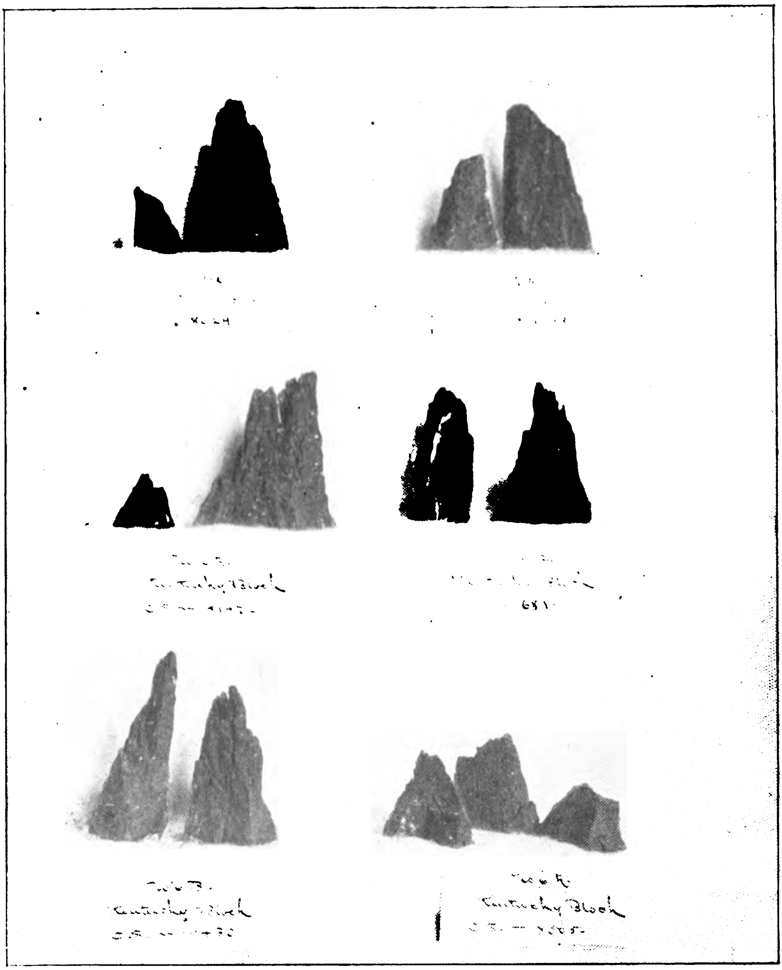
Material.	Laboratory Number.	Character of Surface of whole Brick.	Approximate Size of whole Brick in Inches.	Width at Right Angles to Line of Stress.—Inches.	Length at Right Angles to Line of Stress.—Inches.	Area at Right Angles to Line of Stress.—Square Inches.	Height Parallel to Line of Stress.—Inches.	Load at which Specimen began to Spall.—Pounds.	Load at which Specimen Crushed.—Pounds.	Crushing Strength per Square Inch.—Pounds.	Spall.
Standard Canton Shale Paver. Made from shale obtained at Canton, Ohio. Samples dark red. Furnished by Lyttle & Dolan, ...	2 AF	Unglazed,	8½x4x2½	2.53	2.83	7.15	3.73	38,140	85,115	11,904	
	1 AS	"	"	2.50	2.39	5.98	4.12	82,590	99,280	16,602	
								60,365	Average,	14,253	
Mack Shale, Re-pressed Brick. Made from shale obtained at New Cumberland, W. Va. Samples dark red. Furnished by Huntingdon Construction Co., ...	1 A	Unglazed,	8x4x2½	2.35	3.17	7.45	4.13	62,920	118,170	15,862	
	1 B	"	"	2.37	2.80	6.64	4.15	27,010	93,710	14,113	Light
	2 B	"	"	2.35	2.60	6.11	4.14	50,590	75,510	12,358	Heavy.
	6 A	"	"	2.30	2.70	6.21	4.20	25,850	66,230	10,665	Light.
	6 B	"	"	2.37	2.69	6.38	4.23	44,480	76,760	12,031	Very light.
	5 A	"	"	2.39	2.96	7.07	4.24	21,000	76,710	10,850	Light.
	7 B	"	"	2.43	2.64	6.42	4.24	21,080	64,560	10,056	
								36,133	Average,	12,276	
Monongahela Fire Clay Co.'s sample shale paver. Made from shale obtained at Philipsburg, Pa. Samples dark red. Furnished by Lyttle & Dolan, ...	2 AF	Unglazed,	8½x4x2½	2.45	2.63	6.44	3.82	19,550	66,600	10,342	Light.



FRACTURES OF SETS OF FIRE BRICKS.

DATA OF COMPRESSION TEST OF PAVING BRICKS.

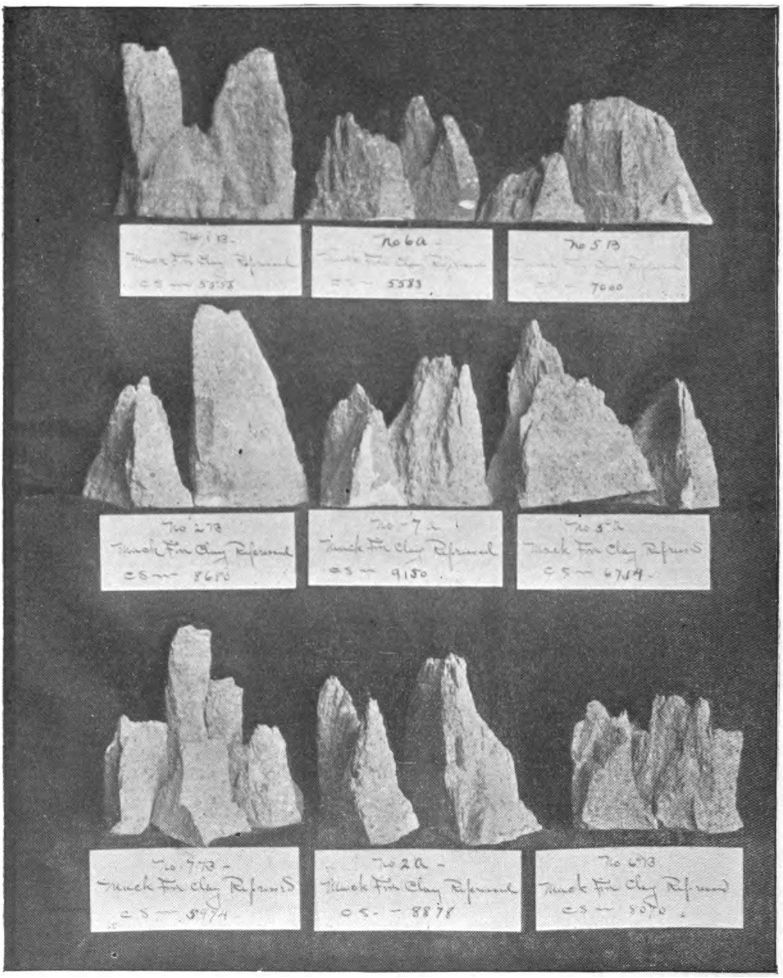
Material.	Laboratory Number.	Character of Surface of whole Brick.	Approximate Size of whole Brick in Inches.	Width at Right Angles to Line of Stress.—Inches.	Length at Right Angles to Line of Stress.—Inches.	Area at Right Angles to Line of Stress.—Square Inches.	Height Parallel to Line of Stress.—Inches.	Load at which Specimen began to Spall.—Pounds.	Load at which Specimen Crushed.—Pounds.	Crushing Strength per Square Inch.—Pounds.	Spall.
Robbins Paver. Made from fire clay obtained at Robbins, Tenn. Samples yellowish-brown. Furnished by Standard Construction Co , ...	6 A	Unglazed,	8½x4x2½	2.48	4.25	10.54	4.21	27,010	52,270	4,959	Light.
	5 A	"	"	2.60	4.42	11.49	4.38	18,760	30,320	2,639	
	1 B	"	"	2.60	4.37	11.36	4.19	18,000	66,810	5,881	
	5 B	"	"	2.57	4.29	11.02	4.37	24,910	50,355	4,569	
	6 B	"	"	2.51	4.14	10.39	4.19	31,970	93.580	9,007	Light.
	2 A	"	"	2.43	4.10	9.96	4.18	41,130	65.260	6,553	
	2 B	"	"	2.46	4.32	10.62	4.23	20,430	75,420	7,101	
								26,030	Average.	5,815	
Hallwood Block (Unglazed Paving Brick). Made from fire clay obtained at Robbins, Tenn. Samples yellow-brown. Furnished by Standard Construction Co., ...	1 B	Unglazed,	9x4x2½	2.48	4.66	11.55	3.67	7.100	50,955	4,412	
	2 B	"	"	2.50	4.66	11.65	3.71	23,760	61,690	5.295	Heavy.
	2 A	"	"	2.50	4.48	11.20	3.72	25,270	74,690	6,668	"
	5 A	"	"	2.53	4.61	11.66	3.78	9,750	58,480	5,015	
	5 B	"	"	2.54	4.50	11.43	3.81	23,640	37,800	3,307	Heavy.
	6 A	"	"	2.49	4.62	11.50	3.82	22,910	55,660	4,840	"
	6 B	"	"	2.46	4.23	10.40	3.82	20,540	28.630	2,752	"
	7 A	"	"	2.51	4.50	11.29	3.68	28,070	48,410	4,288	"
	7 B	"	"	2.52	4.63	11.66	3.64	33,970	73,590	6,311	
								21,668	Average.	4,765	



FRACTURES OF SETS OF FIRE BRICKS.

DATA OF COMPRESSION TEST OF PAVING BRICKS.

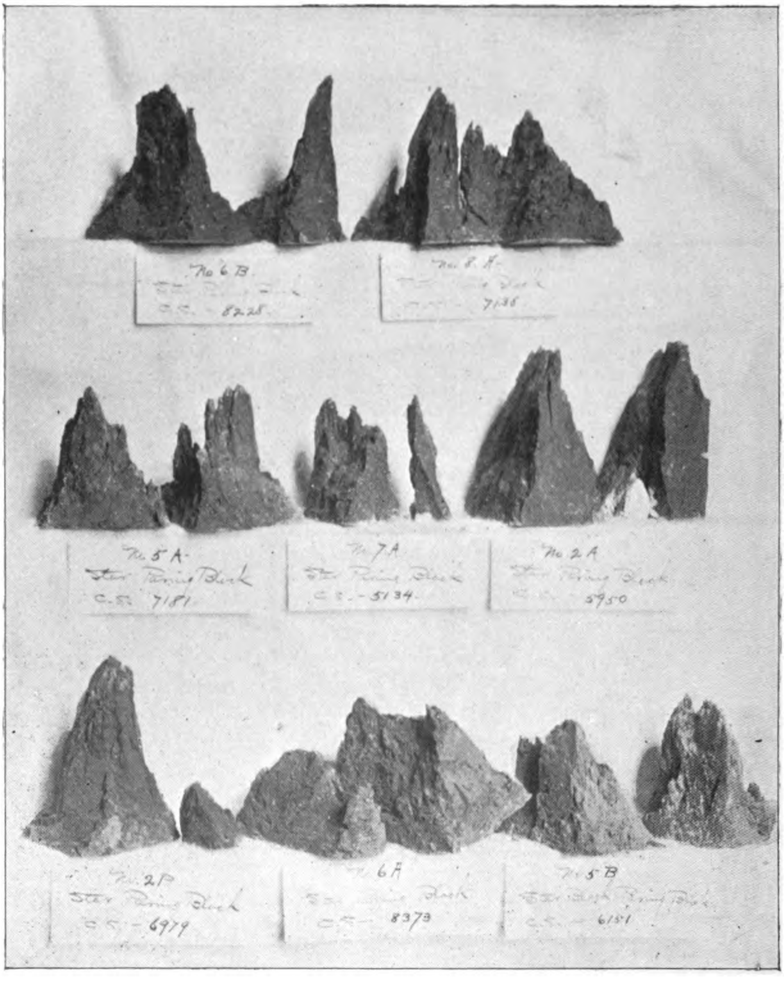
MATERIAL.	Laboratory Number.	Character of Surface of whole Brick.	Approximate Size of whole Brick in Inches.	Width at Right Angles to Line of Stress.—Inches.	Length at Right Angles to Line of Stress.—Inches.	Area at Right Angles to Line of Stress.—Square Inches.	Height Parallel to Line of Stress.—Inches.	Load at which Specimen began to Spall.—Pounds.	Load at which Specimen Crushed.—Pounds.	Crushing Strength per Square Inch.—Pounds.	Spall.
Mack Fire Clay Standard A Square Paving Brick. Made from fire clay obtained at New Cumberland, W. Va Samples yellowish brown. Furnished by Huntington Construction Co., . .	1 B	Unglazed,	8½x4x2½	2.57	3.29	8.45	4.02	65,500	80,900	9.574	
	2 A	"	"	2.55	4.09	10.43	4.00	116,610	120,310	11,535	
	2 B	"	"	2.56	3.42	8.75	4.05	43,600	71,390	8,159	Light.
	5 A	"	"	2.55	3.38	8 62	4.13	61,370	99,710	11.567	
	5 B	"	"	2.54	3.26	8.28	4.12	26,740	95,960	11,590	Light.
	6 A	"	"	2.59	3.26	8.44	4.14	43,990	71,360	8,455	Very light.
	6 B	"	"	2.64	3.33	8.79	4.13	37,620	80,670	9,177	Very light.
	7 A	"	"	2.55	2.65	6.75	4.16	10,000	71,005	10,520	Light.
	8 B	"	"	2.56	3 18	8.14	4.06	45,050	92,020	11,304	Light.
								50,053	Average.	10,209	
Mack Shale Paving Block. Made from shale obtained at New Cumberland, W. Va. Samples dark red. Furnished by Huntington Construction Co., ...	1 A	Unglazed,	9x4x3	3.07	3.21	9.85	3.92	32,450	85.470	8,677	Light.
	1 B	"	"	3.00	3.25	9.75	3.87	44,910	87,910	9,016	Heavy.
	2 A	"	"	3 01	3.17	9 54	3.82	25,280	64,200	6,730	Light.
	2 B	"	"	2.98	2 94	8.76	3 94	47,980	112,210	12 809	Heavy.
	5 B	"	"	3.22	3.00	9.66	3.97	19,270	83,820	8,677	
	5 A	"	"	3.18	2.97	9.44	3.99	12,600	95,200	10,085	
	6 B	"	"	3 10	2.80	8.68	3.96	20,440	113,720	13,101	
								28,990	Average,	9.870	


No 1 B -
Much Fire Clay Refractory
CS — 5558
No 6 A -
Much Fire Clay Refractory
CS — 5583
No 5 B
Much Fire Clay Refractory
CS — 7000
No 2 B
Much Fire Clay Refractory
CS — 8650
No 7 A
Much Fire Clay Refractory
CS — 9150
No 5 A
Much Fire Clay Refractory
CS — 6754
No 7 B -
Much Fire Clay Refractory
CS — 5974
No 2 A -
Much Fire Clay Refractory
CS — 8878
No 6 B
Much Fire Clay Refractory
CS — 5070

FRACTURES OF SETS OF FIRE BRICKS.

DATA OF COMPRESSION TEST OF PAVING BRICKS.

MATERIAL.	Laboratory Number.	Character of Surface of whole Brick.	Approximate Size of whole Brick in Inches.	Width at Right Angles to Line of Stress.—Inches.	Length at Right Angles to Line of Stress.—Inches.	Area at Right Angles to Line of Stress.—Square Inches.	Height Parallel to Line of Stress.—Inches.	Load at which Specimen began to Spall.—Pounds.	Load at which Specimen Crushed.—Pounds.	Crushing Strength per Square inch.—Pounds.	Spall.
Mack Shale Standard A Square Paving Brick. Made from shale obtained at New Cumberland, W. Va. Samples dark red. Furnished by Huntington Construction Co., ...	1 B	Unglazed,	8x4x2½	2.47	4.22	10.42	4.00	44,200	120,880	11,601	Lt. on cors.
	5 A	"	"	2.57	4.25	10.92	4.23	17,530	68,830	6,303	Very light.
	5 B	"	"	2.56	4.30	11.00	4.13	34,000	93,010	8,455	" "
	6 A	"	"	2.47	3 91	9 66	4.16	57,480	109,260	11,311	" "
	6 B	"	"	2.47	4.08	10.07	4.13	17,910	99,610	9,891	" "
	7 A	"	"	2.54	4.18	10.62	4.15	30,000	70,200	6,610	" "
	7 B	"	"	2.54	4.08	10.36	4.17	49,310	91,270	8,810	" "
								35 775	Average,	8,997	
Mack Fire Clay, Re-pressed Paving Block. Made from fire clay obtained at New Cumberland, W. Va. Samples yellowish brown. Furnished by Huntington Construction Co., ...	1 B	Unglazed,	8½x4x2½	2.48	4.26	10.56	4.31	20,730	58,700	5,558	
	2 A	"	"	2.47	4.21	10.39	4.26	67,200	92,250	8,878	Light.
	2 B	"	"	2.45	4.21	10.31	4.27	79.590	89,490	8,680	Very light.
	5 A	"		2.46	4.19	10.3	4.38	31,530	69,150	6,714	Heavy.
	5 B	"	"	2.47	4.30	10.62	4.41	13,230	80,710	7,600	Light.
	6 A	"	"	2.44	4.28	10.44	4.42	28,560	58,290	5,583	Heavy.
	6 B	"	"	2.47	4.28	10.57	4.39	27,560	85,300	8,070	Light.
	7 A	"	"	2.46	4.2	10.33	4.4	61,350	94,320	9,130	"
	7 B	"	"	2.47	4.32	10.67	4.35	12,000	63,740	5,974	"
								37,972	Average,	7,354	

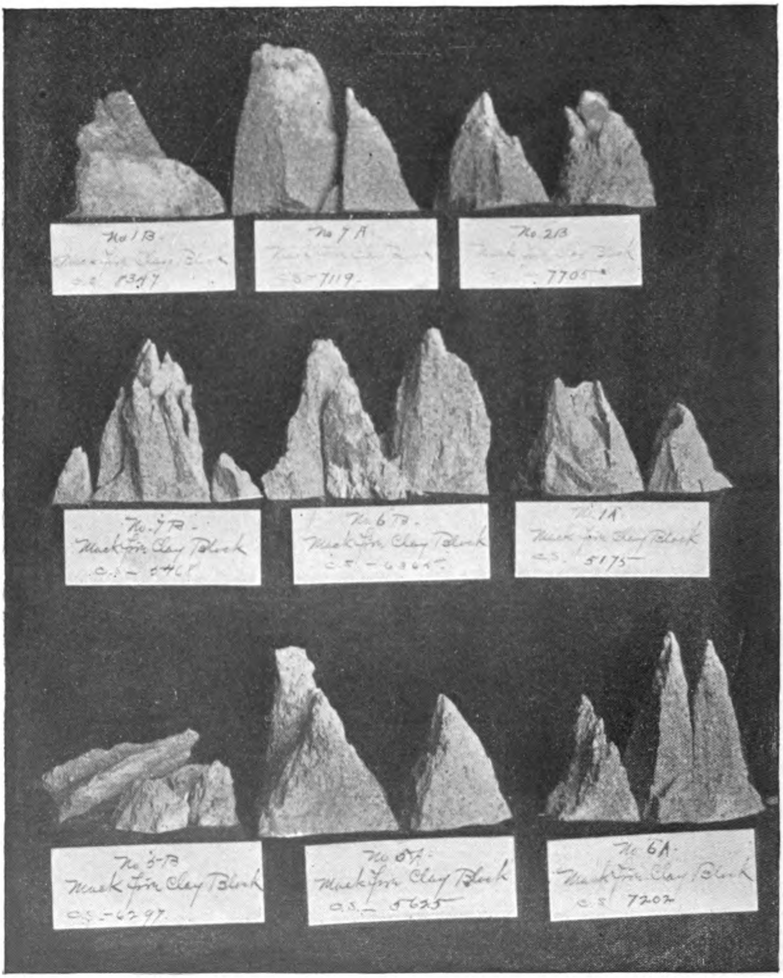


Fractures of Sets of Fire Bricks.

DATA OF COMPRESSION TEST OF PAVING BRICKS.

MATERIAL.	Laboratory Number.	Character of Surface of whole Brick.	Approximate Size of whole Brick in Inches.	Width at Right Angles to Line of Stress.—Inches.	Length at Right Angles to Line of Stress.—Inches.	Area at Right Angles to Line of Stress.—Square Inches.	Height Parallel to Line of Stress.—Inches.	Load at which Specimen began to Spall.—Pounds.	Load at which Specimen Crushed.—Pounds.	Crushing Strength per Square Inch.—Pounds.	Spall.
McManigal Paving Block. Made from plastic clay obtained at Middleport, Ohio. Samples dark brown. Furnished by Grant R. B. Co., ...	1 AF	Glazed,	9x4x3	3.10	2.96	9.17	3.91	13,856	28,560	3,114	Heavy.
	2 AS	"	"	3.08	2.32	7.14	3.90	6,220	17,000	2,380	Light.
								10,038	Average.	2,747	
Star Block Paving Brick. Made from a mixture of shale and fire clay obtained at Portsmouth, Ohio. Samples red brown. Furnished by Charles Spinks & Sons, ...	5 B	Glazed,	9x4x3	3.09	4.48	13.84	4.12	15,500	85,130	6,151	
	6 A	"	"	3.09	4.60	14.21	4.12	29,170	118,990	8,373	
	8 A	"	"	3.06	4.55	13.92	4.13	47,000	99,350	7,138	
	6 B	"	"	3.10	4.57	14.16	4.14	53,780	116,510	8,228	
	7 B	"	"	3.09	4.52	13.96	4.08	24,860	130,000*	9,312	
	5 A	"	"	3.09	4.57	14.12	4.13	42,000	101,400	7,181	
	2 A	"	"	3.12	3.02	9.42	4.09	13,190	56,050	5,950	Very light.
	2 B	"	"	3.11	3.21	9.98	4.10	40,400	69,650	6,979	
	7 A	"	"	3.09	3.22	9.95	4.04	11,730	51,090	5,134	Light.
								30,847	Average.	7,161	

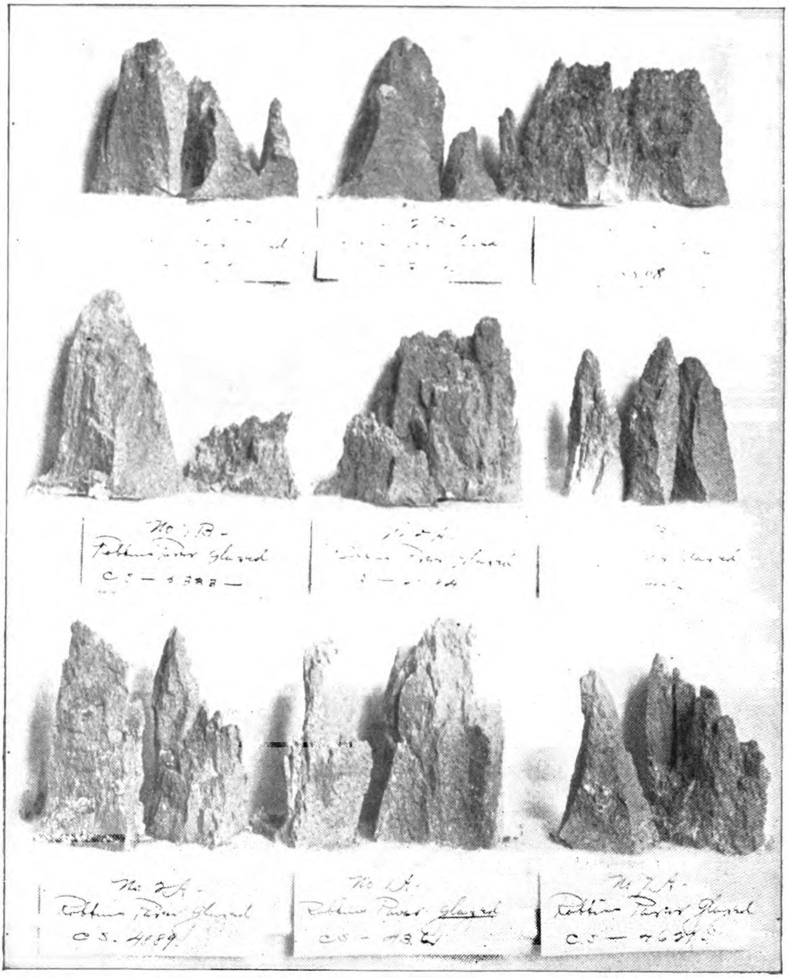
* This brick resisted 128,000 pounds. The machine was not overloaded beyond this point, and the estimated load for crushing of specimen was 130,000 pounds.



FRACTURES OF SETS OF FIRE BRICKS.

DATA OF COMPRESSION TEST OF PAVING BRICKS.

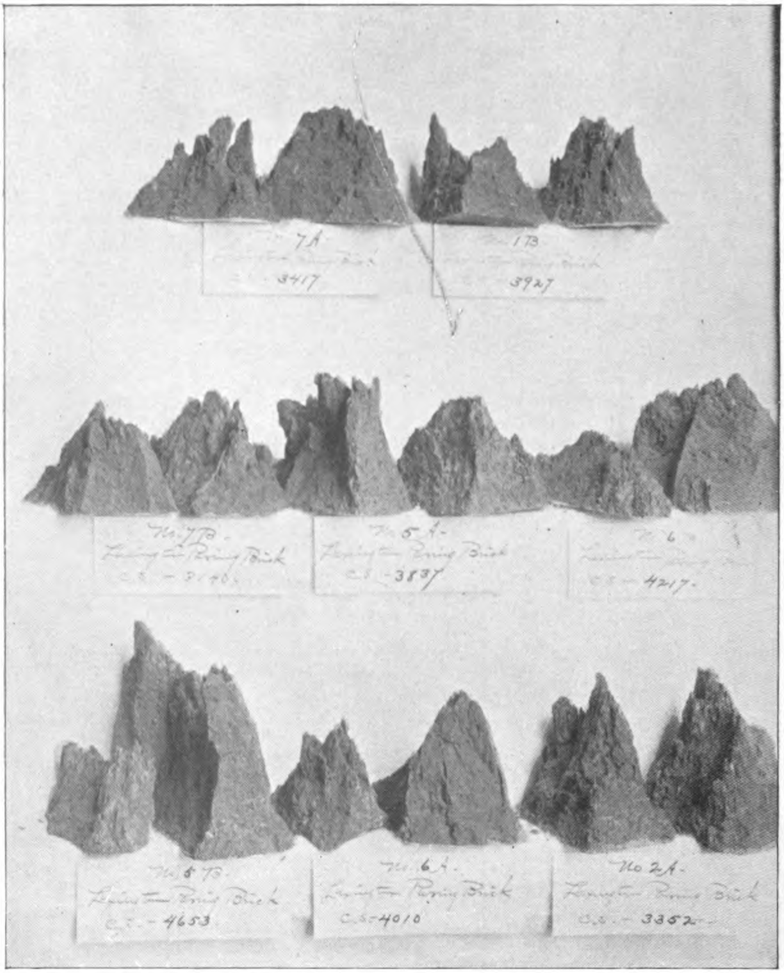
MATERIAL.	Laboratory Number.	Character of Surface of whole Brick.	Approximate Size of whole Brick in Inches.	Width at Right Angles to Line of Stress.—Inches.	Length at Right Angles to Line of Stress.—Inches.	Area at Right Angles to Line of Stress.—Square Inches.	Height Parallel to Line of Stress.—Inches.	Load at which Specimen began to Spall.—Pounds.	Load at which Specimen Crushed.—Pounds.	Crushing Strength per Square Inch.—Pounds.	Spall.
Bannon Paving Brick. Made from fire clay obtained from different parts of Kentucky. Samples brownish red. Furnished by Bannon, ...	1 A	Unglazed,	8½ x 4 x 2½	2.40	2.51	6.03	4.20	10,000	42,800	7,098	Very light.
	1 B	"	"	2.40	2.82	6.76	4.19	23,450	29,715	4,395	Very h'vy.
	5 B	"	"	2.37	2.65	6.28	4.26	19,380	41,690	6,638	
		"									
								17,610	Average,	6,044	
Hallwood Block (Glazed Paving Brick). Made from fire clay obtained at Robbins, Tenn. Samples bluish brown. Furnished by Standard Construction Co., ...	1 B	Glazed,	9 x 4 x 2½	2.67	4.64	12.15	3.91	18,455	64,340	5,295	Deep.
	2 A	"	"	2.56	4.59	11.75	3.94	11,910	43,260	3,681	
	2 B	"	"	2.59	4.56	11.81	3.95	26,580	73,130	6,192	
	5 A	"	"	2.61	4.55	11.87	3.97	19,320	34,410	2,890	Deep.
	5 B	"	"	2.58	4.69	12.10	3.98	30,190	34,380	2,841	"
	6 A	"	"	2.6	4.62	12.01	4.06	19,960	39,500	3,288	"
	6 B	"	"	2.64	4.63	12.22	4.04	18,780	46,330	3,790	
	7 A	"	"	2.58	4.63	11.94	3.93	15,130	51,600	4,320	
	7 B	"	"	2.58	4.52	11.66	3.93	27,480	41,000	3,516	
								20,867	Average,	3,979	
"Riverside Paver." Made from plastic clay obtained at Middleport, Ohio. Samples bluish brown. Furnished by Grant R. B. Co., ...	2 AS	Glazed,	8 x 4 x 2½	2.51	2.62	6.73	3.90	7,030	21,930	3,259	
	1 AF	"	"	2.50	2.61	6.52	3.93	17,300	23,070	3,538	
								12,165	Average,	3,398	



FRACTURES OF SETS OF FIRE BRICKS.

DATA OF COMPRESSION TEST OF PAVING BRICKS.

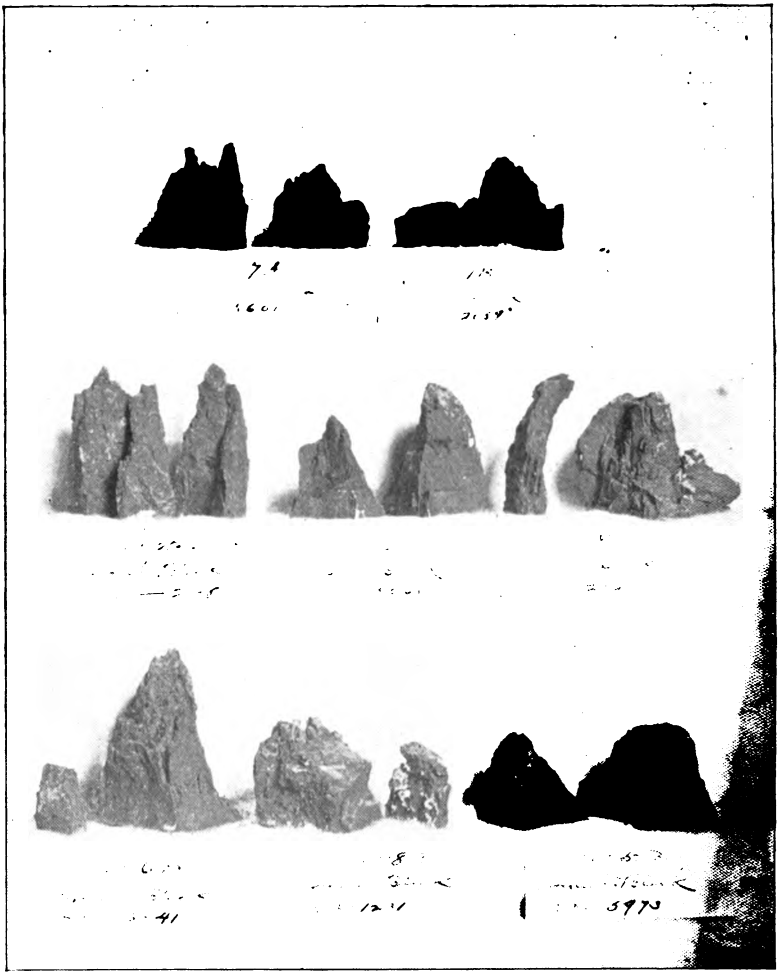
MATERIAL.	Laboratory Number.	Character of Surface of whole Brick.	Approximate Size of whole Brick in Inches.	Width at Right Angles to Line of Stress.—Inches.	Length at Right Angles to Line of Stress —Inches.	Area at Right Angles to Line of Stress.—Square Inches.	Height Parallel to Line of Stress.—Inches.	Load at which Specimen began to Spall.—Pounds.	Load at which Specimen Crushed.—Pounds.	Crushing Strength per Square Inch.—Pounds.	Spall.
Ironton F. B. C. Paver. Made from a mixture of shale and fire clay obtained at Ironton, Ohio. Samples dark yellow-brown. Furnished by Lyttle & Dolan, ...	1 A	Glazed,	9x4x2½	2.68	3.70	9.91	4.25	45,580	62,050	6,261	Deep.
	3 A	"	"	2.62	3.85	10.08	4.43	16,760	80,710	8,006	Light.
	3 B	"	"	2.55	3.77	9.61	4.40	21,500	80,675	8,393	Very light.
	4 A	"	"	2.63	3.73	9.80	4.44	4,000	36,670	3,741	Heavy.
	4 B	"	"	2.63	3.89	10.23	4.51	21,460	42,760	4,179	Deep.
	5 B	"	"	2.60	3.77	9.80	4.47	16,700	67,030	6,840	Very light.
	6 B	"	"	2.65	3.77	9.99	4.38	4,320	92,225	9,222	Light.
								18,617	Average.	6,663	
Mack Fire Clay Block. Made from fire clay obtained at New Cumberland, W. Va. Samples yellowish-brown. Furnished by Huntington Construction Co., ...	1 B	Unglazed,	9x4x3	3.15	4.72	14.87	4.06	118,430	124,220	8,347	Very light.
	1 A	"	"	3.2	3.66	11.71	4.04	27,830	60,610	5,175	Light.
	2 B	"	"	3.26	3.71	12.09	4.04	55,000	93,170	7,705	Deep.
	5 A	"	"	3.18	3.55	11.29	4.04	41,980	63,510	5,625	Light.
	5 B	"	"	3.14	3.72	11.68	4.05	13,970	73 550	6,297	
	6 A	"	"	3.18	3.60	11.45	4.02	36,640	82,470	7,202	Very light.
	6 B	"	"	3.14	3.73	11.71	3.98	25,825	74,540	6,365	Deep.
	7 A	"	"	3.14	3.7	11.6	4.07	53,930	82,590	7,119	
	7 B	"	"	3.18	3.69	11.73	4.04	51,275	64,135	5,468	
								47,209	Average,	6,589	



FRACTURES OF SETS OF FIRE BRICKS.

DATA OF COMPRESSION TEST OF PAVING BRICKS.

Material.	Laboratory Number.	Character of Surface of whole Brick.	Approximate Size of whole Brick in Inches.	Width at Right Angles to Line of Stress.—Inches.	Length at Right Angles to Line of Stress.—Inches.	Area at Right Angles to Line of Stress.—Square Inches.	Height Parallel to Line of Stress.—Inches.	Load at which Specimen began to Spall.—Pounds.	Load at which Specimen Crushed.—Pounds.	Crushing Strength per Square Inch.—Pounds.	Spall.
Robbins Paver—glazed. Made from fire clay obtained at Robbins, Tenn. Samples bluish brown. Furnished by Standard Construction Co., ...	1 A	Glazed,	8½x4x2½	2.66	4.38	11.65	4.28	18,020	50,810	4,361	Deep.
	1 B	"	"	2.66	4.25	11.3	4.27	18,270	60,260	5,333	"
	2 A	"	"	2.45	4.07	9.97	4.21	19,530	48,750	4,889	"
	7 A	"	"	2.53	4.35	11.	4.24	22,050	50,835	4,621	"
	5 A	"	"	2.45	4.24	10.38	4.23	14,200	52,780	5,084	"
	7 B	"	"	2.52	4.2	10.58	4.27	23,690	43,860	4,145	"
	2 B	"	"	2.48	4.28	10.61	4.21	14,410	33,090	3,119	"
	5 B	"	"	2.48	4.24	10.52	4.23	36,350	63,090	5,997	"
	6 B	"	"	2.49	4.22	10.5	4.26	17,270	57,840	5,508	Light.
								20,421	Average,	4,784	
Lexington Paving Brick Made from common clay obtained at Lexington, Ky. Samples dark red. Furnished by Lexington Brick Co, ...	2 B	Unglazed,	8½x4x2½	2½	4¼	10.62	$4\frac{5}{32}$	28,610	28,610	2,693	
	5 B	"	"	$2\frac{17}{32}$	4¼	10.76	$4\frac{5}{32}$	25,520	50,070	4,653	
	6 A	"	"	$2\frac{37}{64}$	4¼	10.96	$4\frac{5}{32}$	19,420	43,950	4,010	
	1 B	"	"	$2\frac{29}{64}$	4¼	10.42	$4\frac{7}{32}$	32,210	40,920	3,927	
	2 A	"	"	2½	$3\frac{15}{16}$	9.69	$4\frac{3}{16}$	16,280	32,480	3,352	
	5 A	"	"	$2\frac{9}{16}$	$4\frac{7}{32}$	10.81	$4\frac{3}{16}$	14,630	41,480	3,837	
	7 B	"	"	$2\frac{15}{32}$	$4\frac{5}{16}$	10.64	$4\frac{3}{16}$	27,460	33,410	3,140	
	6 B	"	"	$2\frac{19}{32}$	$4\frac{13}{64}$	10.88	$4\frac{3}{16}$	21,030	46,470	4,217	
	7 A	"	"	2½	$4\frac{7}{32}$	10.52	$4\frac{15}{64}$	33,490	35,950	3,417	
								24,283	Average.	3,694	



FRACTURES OF SETS OF FIRE BRICKS.

DATA OF COMPRESSION TEST OF PAVING BRICKS.

MATERIAL.	Laboratory Number.	Character of Surface of whole Brick.	Approximate Size of whole Brick in Inches.	Width at Right Angles to Line of Stress.—Inches.	Length at Right Angles to Line of Stress.—Inches.	Area at Right Angles to Line of Stress.—Square Inches.	Height Parallel to Line of Stress.—Inches.	Load at which Specimen began to Spall.—Pounds.	Load at which Specimen Crushed.—Pounds.	Crushing Strength per Square Inch.—Pounds.	Spall.
Grant Block. Made up almost entirely of plastic, or blue clay, obtained at Middleport, Ohio. Samples dark reddish brown. Furnished by Charles Spinks & Sons, ...	1 B	Glazed,	9x4x3	3.06	3.14	9.61	3.98	11,650	19,790	2,059	Heavy.
	2 B	"	"	3.04	3.03	9.21	4.07	13,250	19,885	2,158	"
	5 A	"	"	3.06	3.04	9.3	3.96	13,800	47,055	5,060	
	5 B	"	"	3.06	3.20	9.79	3.91	17,850	58,480	5,973	
	6 A	"	"	3.1	3.07	9.51	3.96	4,730	21,390	2,249	Light.
	6 B	"	"	3.09	3.16	9.76	3.98	21,400	37,490	3,841	"
	7 A	"	"	3.09	3.10	9.58	4.02	27,860	53,665	5,601	Deep.
	8 A	"	"	3.16	3.23	10.21	4.13	12,150	12,420	1,216	
	8 B	"	"	3.73	3.08	11.49	4.13	11,700	14,150	1,231	
								14,932	Average,	3,265	
"Kentucky" Paving Block. Made from a mixture of shale and plastic clay obtained at Portsmouth, Ohio. Samples reddish brown. Furnished by Chas. Spinks & Sons, ...	1 A	Glazed,	9x4x3	2.95	3.2	9.44	3.95	17,450	75,754	8,024	
	1 B	"	"	2.96	2.74	8.11	3.92	4,300	55,250	6,813	Very light.
	2 A	"	"	3.1	3.22	9.98	4.11	34,250	51,465	5,147	Heavy.
	6 A	"	"	2.96	2.73	8.08	3.94	14,920	64,679	8,005	
	6 B	"	"	2.96	2.93	8.67	3.95	52,400	81,760	9,430	
	7 A	"	"	2.97	2 97	8.82	3.88	9,310	81,960	9,293	
								22,105	Average,	7,785	

STRENGTH OF ICE.*

By C. W. Beach, A. M. Munn, and H. E. Reeves, Students in Class of '95, Civil Engineering Course, University of Illinois, Champaign, Ill.

THE comparative scarcity of published records giving experimental data concerning the strength of ice, suggested the desirability of further investigation of the subject. Only two records of compressive tests and one of tensile tests could be found; the first and more elaborate of these was executed by Col. William Ludlow, in 1880 and 1881, in connection with the construction of an ice harbor in the Delaware River, at Liston's Point, and the second tests were made by Fruhling, a German experimenter, about 1885.

Col. Ludlow's experiments, consisting of only eighteen compressive tests, gave a crushing strength, varying from 100 to 1,000 pounds per square inch, with an average of about 575. The ice used by him was of poor quality, a considerable portion being frozen snow, or frozen snow and ice combined. The temperature of the ice during the time of testing ranged from 25° to 31° F., while the temperature of the room varied from 29.6° to 68° F. The distribution of pressure was equalized by placing small blocks of white pine between the faces of the cubes and the upper and lower surfaces of the press. In conclusion, he says that "the minimum pressure requisite to crush ice of the clearest and most compact structure is 1,000 pounds per square inch; that ordinary clear ice, such as we get from the upper Delaware River, would, under certain conditions, resist a pressure of 700 pounds per square inch, and that ice in the condition that we should be likely to find it in the Delaware River, at Liston's Point, would crush with 400 or 450 pounds per square inch or less, from its gradual disintegration by exposure to the sun, air, and salt water."

Fruhling's experiments were made upon clear block ice tested at 23° F. He observes that "as the pressure was increased the cracks became more numerous until they went all through the test piece. As the pressure was further increased the height of the blocks began to diminish, and their cross-section to increase, until ultimately they were flattened out, never, however, giving way suddenly. The only stage in the flattening-out process, at which the pressure was accurately noted, was that at which the height of the block began to diminish." The pressure at which the height began to diminish perceptibly varied from 216 to 380 pounds per square inch, while the pressure at which cracks began to form varied from 60 to 200 pounds per square inch.

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* Extracts from *The Technograph*, No. 9.

The crushing tests of ice executed by the writers were made with a 100,000-pound Riehlé Testing Machine. The test pieces were sawn from blocks of ice, and their surfaces were planed down by means of a straight-edge made from a thin bar of iron. The cubes were crushed between sheets of heavy card-board, which served effectually to cushion the compressed surfaces. To prevent concentration of pressure, due to non-parallelism of opposite faces of the cube, or of the testing machine, the adjustable compression-plate shown in Fig. 1 was used.

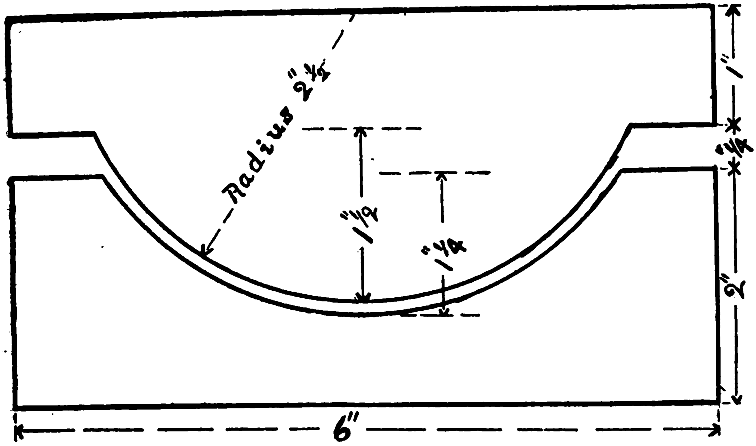

FIG. 1.

This device consists of two thick circular plates, six inches in diameter, the top face of the upper and bottom face of the lower being true planes. On the lower side of the upper piece is a solid spherical segment which fits into a spherical socket in the top of the lower casting. The surfaces in contact are smoothly and accurately shaped. By thorough lubrication of the segment an exceedingly delicate equalization is secured, even under the heaviest pressures.

At the time the experiments were undertaken natural ice had not formed of sufficient thickness to afford test cubes. A cake of artificial ice 14x14x30 inches was procured. From it were prepared four-

TABLE I.

Data on the Crushing Strength of Ice Cubes.

Experiments Made at the Testing Laboratory of the University of Illinois.

No. of Piece.	Date.	Kind of Ice.	Temperature.			Dimensions of Specimens in Inehes.		Direction of Applied Pressure with Reference to Columnar Disintegration.	Total Pressure at which Cracks first appeared, Pounds.	Ultimate Crushing Strength in Pounds.*		Remarks.
			External Air.	Laboratory.	Ice at Time of Testing.	Sides.	Depth.			Total.	Per Sq Inch.	
			F.	F.	F.							
1	Dec. 27, '94,	Artificial,	17 6°	25.7°	25.7°	4 x4¼	4¼	Parallel, . . .	4,000	5,400	318	Gave away gradually; piece filled with iron rust and air bubbles.
2	"	"	"	"	"	"	4	Perpendicular,	3,500	12,300	724	Broke suddenly with loud report; split in diagonal plane.
3	"	"	"	"	"	4⅛x4⅛	4	"	4,500	12,000	705	Gave way gradually; broke into small pieces when struck light blow with hammer.
4	"	"	"	"	"	4 x4¼	4	"	3,300	7,800	459	Broke suddenly with report.
5	"	"	"	"	"	4¼x4¼	4	"	3,000	10,500	564	Specimen from corner of block; broke suddenly with report.
6	"	"	"	"	"	4 x4¼	4¼	Parallel, . . .	1,800	6,700	394	One side gave way before the other.
7	"	"	"	23°	23°	4⅛x4½	4	" . . .	2,000	13,700	736	At 2,000 pounds a crack appeared diagonally across the piece and extending through it.
8	"	"	"	"	"	4¼x4	4½	" . . .	2,000	12,100	712	Broke suddenly with report.
9	"	"	"	"	"	3¾x5	4½	" . . .	1,800	8,000	428	Specimens from corner of block; axes of columns on one side were vertical, and on the other side horizontal; diagonal line marking end of columns plainly visible.
30	Dec. 29, '94,	"	14.9°	30.2°	14°	3¾x4¼	3⅞	Perpendicular,	5,200	17,200	1,080	Gave way gradually.
31	"	"	"	"	"	4 x4	4	"	7,000	15,400	963	One corner chipped off; crushed suddenly.
32	"	"	"	"	"	3⅞x4	4	"	4,600	16,000	1,032	Centre and sides crushed out; broke suddenly with report.
33	"	"	"	"	"	4 x4	3⅞	Parallel, . . .	4,200	5,400	327	Broke suddenly on one corner with report.
34	"	"	"	"	"	3⅞x4⅛	4	" . . .	5,200	15,400	969	Gave way gradually.
35	"	"	"	"	"	6 x6	5⅞	Perpendicular,	10,000	34,600	962	Gave way gradually.
36	"	"	"	"	"	5¾x6	6	Parallel, . . .	7,200	25,700	775	Broke suddenly with loud report.

37	Dec. 29, '94,	Artificial,	14.9°	30.2°	14°	6 x6	5⅞	Perpendicular,	11,200	30,000	834	Broke suddenly with loud report.
38	"	"	"	"	"	6⅛x6	"	"	10,200	25,500	695	One side chipped off at 15,700; broke with report.
39	"	"	"	"	"	6 x6	"	Parallel, . . .	8,400	30,400	844	Broke suddenly with report.
10	Dec. 27, '94,	"	17.6°	23°	23°	6⅜x6½	6	Perpendicular,	12,000	29,800	719	Broke suddenly with report.
11	"	"	"	"	"	6¾x6½	5¾	"	11,600	27,400	623	Broke suddenly with report.
12	"	"	"	"	"	6½x6½	"	"	10,400	28,900	684	Gave way gradually.
13	"	"	"	"	"	6½x6¾	6	"	12,000	31,300	712	Broke suddenly with report.
14	"	"	"	"	"	6¼x6⅛	6⅛	Parallel, . .	12,200	17,500	456	Broke suddenly; piece failed at point where last ice was formed.
15	"	"	"	"	"	6½x6	6	" . . .	8,400	14,600	372	One-half the block failed, the other half did not crush. Failed as No. 14.
16	"	"	"	"	"	6 x6¼	6½	" . . .	10,200	28,500	759	Broke suddenly along diagonal plane from corner of original block to opposite.
17	"	"	"	"	"	6 x6½	6½	" . . .	6,200	24,000	615	Failed in same manner as No. 16. Line of failure plainly visible while under pressure.
40	Nov. 31, '94,	Natural,	21.2°	"	12.2°	4 x4	4	Perpendicular,	13,600	19,800	1,239	Broke suddenly with report.
41	"	"	"	"	"	"	3⅞	Parallel, . . .	13,000	23,700	1,608	Broke suddenly with report.
42	"	"	"	"	"	4 x4⅛	4⅛	Perpendicular,	. . . .	17,000	1,031	Broke suddenly without warning.
43	"	"	"	"	"	4⅛x4⅛	3⅞	Parallel, . . .	12,000	29,500	1,735	Broke suddenly. Cracking continued from 13,000 pounds on.
44	"	"	"	"	"	4 x3⅞	4	Perpendicular,	11,200	28,600	1,844	Similar to No. 43.
45	"	"	"	"	"	4¼x4	3⅞	Parallel, . . .	31,000	47,800	2,818	Broke suddenly with loud report. The boards under bearing surface crushed suddenly and probably caused premature failure.
46	"	"	"	"	"	4 x4⅛	3⅞	Perpendicular,	. . . .	12,000	728	Corner chipped off at 4,000 pounds. Evidently the bearing surface was imperfect.
47	"	"	"	"	"	3⅞x4⅛	4	Parallel, . . .	. . . .	31,600	1,975	At 28,000 pounds one corner chipped off. Broke suddenly with loud report.
48	"	"	"	"	"	4 x4⅛	4	Perpendicular,	. . . .	6,000	364	One corner chipped in preparing the piece. Failed suddenly.
49	Dec. 31, '94,	"	"	"	"	4¼x4	4	Parallel, . . .	1,300	26,300	1,649	Broke suddenly with report.
50	"	"	"	"	"	3⅞x4	4	Perpendicular,	10,000	13,200	852	Broke suddenly with report.
51	"	"	23°	"	"	4 x4	3⅞	Parallel, . . .	11,800	25,400	1,588	Broke suddenly with report.
52	"	"	"	"	"	4 x3⅞	4	Perpendicular,	. . . .	11,700	755	Broke suddenly without warning.
53	"	"	"	"	"	4 x4	3⅞	Parallel, . . .	22,000	30,500	1,905	Broke suddenly with report.
54	"	"	"	"	"	"	3¾	Perpendicular,	7,000	16,700	1,044	Corner chipped off at 3,500 pounds.
55	"	"	"	"	"	"	3⅞	Parallel, . . .	11,000	26,700	1,481	Broke suddenly with report.

* The pressure was applied at an average rate of 10,000 pounds per minute.

teen 4-inch and thirteen 6-inch cubes, besides a number of small slabs. This ice was manufactured in the usual manner—that is, by immersing cans filled with water in cold brine. The ice first forms on the sides and bottom of the can and gradually freezes to the centre. Most of the impurities of the ice are thus concentrated at the centre of the cake, together with the air contained in the water.

The natural ice was obtained from a pond near by, and was quite free from air bubbles and impurities.

Ice, when subjected to pressure, is resolved into columns whose direction is normal to the surface which was in contact with the water while freezing. In natural ice these columns are parallel, hence the pressure is always applied perpendicular or parallel to them. By examining Table II it will be seen that those pieces tested with the pressure parallel to the columns developed about 77 per cent. greater strength than those tested with the pressure perpendicular to the column. Test piece No. 45 gave a very high result—2,818 pounds per square inch. This piece was remarkably clear and free from air bubbles. Rejecting it, the percentage is reduced to 63.

In artificial ice the columns extend from the side toward the centre, and from the bottom up. In cubes cut from the corners of a cake of artificial ice the columns were found to cross or intersect at right angles, and in such cubes the fracture is always in a plane cutting the diagonally opposite edges, the one half sliding on the other. It is possible, therefore, by selecting test pieces from different parts of the original cake, to obtain widely-varying results for the crushing strength. The great difference between the average crushing strength of natural and artificial ice is thus easily explained.

It was found that in homogeneous ice the phenomenon of failure by crushing is similar to that of cubes of sandstone tested in a like manner—that is, a cone is forced out from each of the four vertical sides.

A few small pieces of ice were crushed at 32° F., mainly for the purpose of observing the phenomena due to crushing at that temperature. In every such case the ice gave way gradually and changed form slowly. Ice at this temperature possessed quite a degree of plasticity and exhibited scarcely any of the phenomena shown by ice crushed at lower temperatures.

It would be of interest to make a series of tests through a great range of temperature and plot the results, so as to show the relation between strength and temperature.

TABLE II.

SUMMARY OF TABLE I.

	Pounds per square inch.
Mean strength of five 4-inch cubes of artificial ice, tested at 25.7° F.,	569
Mean strength of three 4-inch cubes of artificial ice, tested at 23° F.,	625
Mean strength of eight 6-inch cubes of artificial ice, tested at 23° F.,	617
Mean strength of all cubes of artificial ice, tested at 23° F.,	620
Mean strength of four 4-inch cubes of artificial ice, tested at 14° F.,	1,011
Mean strength of five 6-inch cubes of artificial ice, tested at 14° F.,	822
Mean strength of all cubes of artificial ice, tested at 14° F.,	906
Mean strength of all cubes of artificial ice tested,	560
Mean strength of seven 4-inch cubes of natural ice, with direction of pressure perpendicular to columns, tested at 12.02° F.,	1,070
Mean strength of eight 4-inch cubes of natural ice, with direction of pressure parallel to columns, tested at 12.2° F.,	1,845
Mean strength of all cubes of natural ice tested,	1,451

Experiments were also made upon the crushing strength of slabs of ice, the results of which are shown in Tables III and IV:

TABLE IV.

SUMMARY OF TABLE III.

	Pounds per square inch.
Average of all natural ice slabs tested,	777
Average of the four most nearly perfect slabs of natural ice,	932
Average of all slabs of artificial ice tested,	718
Average of nine most nearly perfect slabs of artificial ice tested,	763

TENSILE STRENGTH.

The tests for tensile strength were made with a Riehlé cement testing machine. The briquettes were made by placing the brass cement briquette molds in a shallow pan of water and allowing it to freeze. The briquettes were easily removed from the molds by allowing a stream of water to flow over them for a short time, their cross-section not being sensibly reduced by this operation. Nos. 21, 22, 23, and 27 were shaved to a less cross-section than one square inch. By reducing the cross-section, and thereby the ultimate strength, a greater and more nearly correct value of the unit tensile strength at that temperature was obtained. A large per cent. of the briquettes broke in the grips, due to cross-stresses induced by partial crushing. It would seem from the experiments that a slight difference in temperature makes considerable difference in the tensile strength of ice.

From these experiments the following conclusions may be drawn:

TABLE III.

DATA ON THE CRUSHING STRENGTH OF ICE SLABS.

Experiments Made at the Testing Laboratory of the University of Illinois.

No. of Piece.	Date.	Kind of Ice.	Temperature.			Dimensions of Specimens in Inches.		Direction of Applied Pressure with Reference to Columnar Disintegration.	Total Pressure at which Cracks first appeared. Pounds.	Ultimate Crushing Strength in Pounds.		Remarks.
			External Air.	Laboratory.	Ice at Time of Testing.	Sides.	Depth.			Total.	Per Sq. Inch.	
			F.	F.	F.							
18	Dec. 27, '94	Artificial,	17.6°	23°	23°	3⅝x4¼	2¼	Perpendicular,	5,000	16 700	1,062	Resolved into columns perpendicular to direction of force.
19	"	"	"	"	"	4¼x4	2⅜	"	2,400	7,200	436	Broke suddenly with report. Columns parallel to force.
20	"	"	"	"	"	4 x4	2⅜	"	1,400	7,500	469	Broke suddenly with report.
21	"	"	"	"	"	4 x4⅜	1¾	"	3,300	13,200	755	Broke suddenly with report.
22	"	"	"	"	"	3⅞x3¾	1⅝	"	2,000	20,400	915	Failed gradually.
23	"	"	"	"	"	3¼x5½	1⅜	"	2,000	13,400	749	Failed gradually.
24	"	"	"	"	"	2⅜x5½	2⅛	"	3,000	4,800	393	Broke suddenly. Centre of block full of air bubbles.
25	Dec. 28, '94	"	12.2°	"	"	2 x3	1⅞	"	2,200	5,600	933	Broke suddenly with report.
26	"	"	"	"	"	4 x4⅜	1¾	"	2,800	13,000	743	Broke suddenly with report.
27	"	"	"	"	"	4 x4⅛	1⅝	Parallel, . . .	2,200	13,300	806	Broke suddenly with report.
28	"	"	"	"	"	4¼x5⅛	1⅝	" . .	2,600	21,800	813	This piece came from centre of block and was full of rust and air bubbles.
29	"	"	"	"	"	4¼x5¾	2	" . . .	4,200	13,500	551	Broke suddenly. Full of rust and air bubbles.
56	Dec. 31, '94	Natural,	23°	"	12.2°	6 x4	1¾	Perpendicular,	2,200	35,000	1,459	Broke suddenly.
57	"	"	"	"	"	5¾x4	1⅞	"	8,000	17,000	739	Broke suddenly. Flaw in piece.
58	"	"	"	"	"	4 x5⅞	1⅞	"	10,000	25,800	1,099	Failed gradually.
59	"	"	"	"	"	4 x6	1⅞	"	. . . .	11,000	458	Broke suddenly. Specimen imperfect.
60	"	"	"	"	"	4 x5⅞	1⅞	"	7,000	1,700	724	Failed on one side.
61	"	"	"	"	"	4 x6	2	"	4,800	10,300	429	Broke suddenly with report.
62	"	"	"	"	"	4 x6	1¾	"	4,000	17,800	742	Broke suddenly with report.

1. Ice, when subjected to pressure, is resolved into columns normal to the natural surface.

2. The greatest strength is obtained when the direction of applied pressure is parallel to the columns, and least when perpendicular to them.

3. Ice subjected to pressure at 32° F. readily changes form.

4. Variations in temperature produce a perceptible influence on both compressive and tensile strength of ice.

TABLE V.

DATA ON TENSILE STRENGTH OF NATURAL ICE.

Experiments made at the Testing Laboratory of the University of Illinois.

No. of Piece.	Date.	Temperature.		Section in Inches.	Ultimate Pressure in Pounds.	Tensile Strength in Pounds per Square Inch.	Location of Break.
		External Air.	Ice at Time of Testing.				
1	Dec. 28, '94, . .	13.1° F.	19.4° F	1x1	102	102	Centre.
2	" . .	"	"	"	132	132	Imperfect.
3	" . .	"	"	"	179	179	Centre.
4	" . .	"	"	"	163	163	Centre.
5	" . .	"	"	"	239	239	Centre.
6	" . .	"	"	"	228	228	Upper grip.
7	" . .	"	"	"	174	174	Lower grip.
8	" . .	"	"	"	191	191	Lower grip.
9	" . .	"	"	"	200	200	Lower grip.
10	" . .	"	"	"	218	218	Lower grip.
11	" . .	"	"	"	156	156	Lower grip.
12	" . .	"	"	"	215	215	Centre.
13	" . .	"	"	"	165	165	Centre.
14	" . .	"	"	"	200	200	Lower grip.
15	" . .	"	"	"	208	208	Centre.
16	" . .	"	"	"	126	126	Centre.
17	" . .	"	"	"	178	178	Centre.
18	" . .	"	"	"	221	221	Lower grip.
19	Dec. 31, '94, . .	21.2° F.	23° F .	"	120	120	Centre.
20	" . .	"	"	"	110	110	Lower grip.
21	" . .	"	"	1x⅞	167	175	Lower grip.
22	" . .	"	"	⅞x⅞	196	256	Lower grip.
23	" . .	"	"	1x⅞	138	158	Lower grip.
24	" . .	"	"	1x1	120	120	Upper grip.
25	" . .	"	"	"	106	106	Centre.
26	" . .	"	"	"	153	153	Centre.
27	" . .	"	"	1x⅞	122	139	Centre.
28	" . .	"	"	1x1	124	124	Lower grip.
29	" . .	"	"	"	160	160	Upper grip.
30	" . .	"	"	"	167	167	Centre.
31	" . .	"	"	"	159	159	Lower grip.
32	" . .	"	"	"	148	148	Centre
33	" . .	"	"	"	118	118	Lower grip.
34	" . .	"	"	"	120	120	Lower grip.

TABLE VI.

SUMMARY OF TABLE V.

	Pounds per square inch.
Average of briquettes tested at a temperature of 19.4° F. which broke in centre,	184
Average of briquettes tested at a temperature of 23° F. which broke in the centre,	139
Average of briquettes tested at 19.4° F. that broke in the grips,	191
Average of briquettes tested at 23° F. that broke in the grips,	150
Average of all briquettes tested that broke in the centre,	160
Average of all briquettes tested that broke in the grips,	169
Average of all briquettes tested at 19.4° F.,	183
Average of all briquettes tested at 23° F.,	146
Average of four pieces tested with a less cross-section than one square inch at 23° F.,	182
Average of all briquettes tested,	165

The results of five tests made by Fruhling at a temperature of 23° F. gave an average tensile strength of 189 pounds per square inch. The cross-section of his specimens was 0.77 square inches.

DR. ROBERT H. THURSTON.

Pioneer in Scientific Experimental Engineering.

TO Dr. Robert H. Thurston, director of Sibley College, the School of Mechanical Engineering of Cornell University, whose portrait appears in this number, and whose originality, thoroughness of investigation, and prolific writing has made his name famous throughout the engineering world, is due the honor of having contributed more in the last twenty years toward a better knowledge of the physical properties of engineering materials, in all possible forms of their application, than has been accomplished in any half-century before.

Robert H. Thurston, born in Providence, R. I., October 25th, 1839, of a family of the old Viking stock, was the son of Robert Lawton Thurston, a distinguished inventor and mechanic, who founded what is now the Providence Steam Engine Co. The son inherited his father's talents, but confined himself more to the theoretical than to the practical side of engineering. His early training was received in the public schools of Providence, where, during holidays and vacations, he picked up much valuable practical experience in his father's works. At the age of sixteen he entered the class of '59 at Brown University, in which year he received the degrees of Ph. B. and C.E., and, later, those of M. A. and LL. D.

In 1861, after a short business experience with his father, Dr. Thurston entered the Engineer Corps of the United States Navy, and served with distinction throughout the war, attaining, in 1865, the rank of First Assistant Engineer, when he was detailed to the professorship of natural and experimental philosophy in the United States Naval Academy. His success as a teacher of science was remarkable, and in 1870 he was called to the chair of Mechanical engineering at the then newly-founded Stevens Institute of Technology, Hoboken, where, in 1871, he organized the first mechanical laboratory founded as a department of education in a school of mechanical Engineering. It was here that he discovered the exaltation of the normal elastic limit in iron and steel, and carried on the first and only complete systematic investigation of the strength and ductility of the copper-tin-zinc alloys, discovering, in 1873, the maximum alloys of the Kalchoid series. It was here, also, that he first discovered and investigated the variation due to orthogonal strains in the elastic limit of metals, conducted the first investigation of the principal methods of strain on timber, discovered the fact of an increased power of resisting stress which was developed in iron and steel by their subjection to a strain which produced distortion beyond the elastic limit and gave them set, and here that he wrote most of the papers on the strength of materials that have since given him such a world-wide reputation.

Dr. Thurston spent the summer of 1873 at Vienna as member of the International Jury of the United States Scientific Commission. He was also a member of the committee of the American Society of Mechanical Engineers promoting the Centennial Exposition of 1876. He was given an "*Ehren Diplom*" at Vienna, and a medal and diploma at Philadelphia for his autographic testing machine. He was the first President of the American Society of Mechanical Engineers, three times Vice-President of the American Association for the Advancement of Science, Vice-President of the British Association, and Vice-President of the American Institute of Mining Engineers. He is a member of the principal European Scientific and Engineering Societies, Officer de l'Instruction Publique de France, member of the military order of the Loyal Legion, member of the American Society of Civil Engineers, and honorary member of the Franklin Institute.

So eminently successful was Dr. Thurston's career that in 1885 he was invited to assume the directorship of the Sibley College of Mechanical Engineering, then proposed to be organized at Cornell University, which position was created for him. The evolution of the college had been rapid, its student-body having increased over a thousand per cent. in ten years. Under the Doctor's masterful directorship it stands to-day one of the first schools of mechanical engineering in the country. In 1890 and in 1895, at the expiration of five and of ten years of services, respectively, he surrendered his plenipotentiary power to the trustees of the University; but it was not accepted, and he was requested to remain and to continue to exercise the powers originally conferred upon him.

Outside his college work Dr. Thurston always had a professional practice, and has continued to publish books, reports, and technical papers, bringing up the number of his writings to above two hundred and fifty. Among his best known works are: *A History of the Steam Engine*, *A Manual of the Steam Engine*, *Materials of Engineering*, etc., etc.

In the summer of 1889 he was called to act upon the International Jury held in Paris, and was made by the French government "Officer de l'Instruction Publique," receiving also a double nomination by the Jury and by the U. S. Commission as Officer of the Legion of Honor. He was also on the International Jury at Chicago in 1893, and was assigned to special duty in direct connection with the office of the committee on awards.

Dr. Thurston's large experience of the world, keen insight into human nature, gracious manner, and great kindness of heart admirably fit him for the position he holds. He has ever a kind word for the students in difficulties, and a warm hand-clasp for those he meets in after years, which has won for him the deep and lasting esteem of the thousand of students who have had the privilege of being guided by and knowing a man of his unusual attainments.

STEEL CASTINGS AND MALLEABLE IRON.

By C. H. Benjamin, Professor of Mechanical Engineering, Case School of Applied Science, Cleveland, Ohio.

I HAVE noticed of late some discussion in the technical journals with regard to the peculiarities and relative merits of so-called steel castings and malleable or annealed castings.

I have from time to time had occasion to conduct numerous tests on the metals included under the above heads, and think that some of the results may be of sufficient interest for publication.

Steel castings are used quite generally by machinery manufacturers, instead of wrought iron or bronze, in places where cast iron is inadmissible, but I think they are used without any definite idea of their strength or fitness.

I also suspect that steel castings are often malleable castings under another name, and are neither better nor worse than the latter.

To procure material for tests patterns suitable for test, pieces were made and sent to the different manufacturers, who advertise to make small steel castings for the trade.

Six tension pieces and six compression pieces were thus obtained of each of four firms, one doing business in Massachusetts, one in New York, and two in Pennsylvania. The castings were obtained through outside parties and nothing was said about testing them, as the idea was to get fair samples of castings supplied to the trade.

I will denote the different series as A, B, C, and D, without giving the names of the makers. The tension pieces in each series were of standard shape, eight inches between marks, and about ⅜x1.2 inches in cross-section.

The compression pieces were cylindrical, two inches long and about three-fourths of an inch in diameter.

In general these specimens may be considered as representing the character of the steel in small castings made by the different firms represented.

Three tension and three compression pieces in each series were tested in a rough condition, just as they came from the foundry or the annealing furnace, while the other three of each kind were finished by removing the scale to about the same depth as in ordinary machine finishing. The extensometer used in making the tests was one invented by the writer, and illustrated in the January issue of this magazine, and the tests were all made on a Riehlé machine. Table I gives a summary of the experiments as far as completed.

The three sets, A, B, and D, were probably made of a steel comparatively high in carbon and were then softened by some sort of an annealing process, as is the case with malleable castings. This is evidenced by the comparatively sharp corners on these castings, showing a high temperature in pouring, and by a thin skin of softer metal on the outside. This latter peculiarity is plainly shown in the fractures of the tension pieces.

The castings in series C showed none of these characteristics, and were probably a low grade steel not subjected to any annealing. They were harder and stronger than the others, less uniform in character, and did not possess much ductility.

The rounded corners showed that the steel was hardly thin enough to run in such thin castings. One manufacturer, to whom application was made, failed entirely from a similar cause.

The figures in the table represent in each case the average results from two or three experiments.

The elastic limit was determined by taking numerous readings from the extensometer, plotting the usual elastic curves, and thus locating by inspection the points where a change occurred in the rate of extension or compression.

The modulus of elasticity was calculated from the stress and distortion at the elastic limit.

In series A and B the elastic limit is about one-half the ultimate strength. In series C and D there is such a lack of uniformity in the elasticity as forbids any attempt at averaging, and this fact alone should condemn them for use in machinery.

The percentage of elongation is seen to be very small, the material in this respect resembling cast iron rather than steel. The contraction of area was too slight to be measured.

One interesting phenomenon was noticed during the elongation. A strip of metal along the centre line of the test piece seemed to have been less affected by the annealing than the parallel edges, and to be less ductile, so that minute cracks would be seen extending across this strip at intervals, some time before the fracture of the specimen as a whole.

The failure of the compression specimens was in every case by bending out of the vertical in a curve of double flexure, and finally tipping over, so that no values of maximum strength could be obtained. The pressure in some instances was carried as high as 135,000 pounds per square inch.

The values of the elastic limit were determined in the same manner as with the tension pieces, and the curves plotted are somewhat similar, save that the elastic is very low as compared with the ultimate strength of the metal. The pieces showed no signs of fracture during the tests.

TENSION.

Series No.	Rough or Finished.	Length. Inches.	Breadth. Inches.	Thickness. Inches.	Area of Section.	Elastic Limit.	Ultimate Strength.	Elongation.		Modulus of Elasticity.
								Inches.	Per Cent.	
A	Rough,	8	1.227	.389	.478	17,060	38,940	.09	1.12	34,510,000
	Finished,	8	1.157	.307	.355	19,480	39,600	.04	0.5	34,919,000
B	Rough,	8	1.233	.392	.484	18,640	38,490	.17	2.15	20,643,000
	Finished,	8	1.165	.311	.363	17,490	33,990	.13	1.6	31,536,000
C	Rough,	8	1.234	.385	.476	. . .	55,320	.08	1.	24,263,000
	Finished,	8	1.114	.317	.354	. . .	75,130	.07	0.9	31,680,000
D	Rough,	8	1.23	.386	.475	. . .	35,180	.06	0.8	27,205,000
	Finished,	8	1.19	.33	.394	. . .	32,600	.04	0.5	23,795,000

COMPRESSION.

Series No.	Rough or Finished.	Length. Inches.	Diameter. Inches.	Area of Section.	Elastic Limit.	Modulus of Elasticity.
A	Rough,	2	.7744	.471	34,630	4,105,000
	Finished,	2	.7496	.441	31,940	5,097,000
B	Rough,	2	.7902	.490	30,770	4,934,000
	Finished,	2	.687	.371	25,610	6,791,000

Series C and D were not tested for compression.

One object of these experiments was to determine the effect of removing the scale on the strength of the metal, but I must confess that the results were rather disappointing, as far as arriving at any exact conclusion is concerned.

By reference to the table it will be seen that the specimens in series A were not materially affected in strength by finishing, that those in series B and D became weaker and less ductile by removing the outside skin, showing that the best metal was on the outside, and, finally, that the specimens in series C became apparently stronger by finishing.

I am inclined, however, to attribute this latter result to a lack of uniformity in the metal, as the specimens in series C were very deficient in this respect.

A series of experiments were made to determine the shearing strength of the metal in series A and B, the average results being as follows:

Series A, ultimate shearing strength, 56,700.
Series B, ultimate shearing strength, 42,900.

The conclusions to be drawn from these few experiments may be summed up as follows:

1. That ordinary small steel castings, such as may be purchased in the market, have an ultimate tensile strength varying from 33,000 to 44,000 pounds per square inch, or an average of about 37,500 pounds.

2. That the elastic limit may be safely taken at fifty per cent. of the ultimate tensile strength.

3. That the value of the modulus of elasticity varies from 20,000,000 to 35,000,000, with an average value of 28,500,000.

4. That the elastic limit of compression varies from 25,000 to 35,000 pounds per square inch, with an average value of 30,000 pounds.

5. That the effect of removing the scale on the strength of a steel casting depends entirely on the nature of the treatment to which the metal has been exposed in casting and in annealing.

MALLEABLE CASTINGS.

The results which I have obtained from ordinary malleable castings are so nearly the same as to need no special comment, and the appearance of the fractures is much the same. I have summarized the results of a number of tests as follows:

TENSILE STRENGTH OF MALLEABLE IRON.

Ultimate (average of 12 tests),	38,270 pounds.
" (average of 10 tests),	36,160 "
Elongation (average of 12 tests),	0.97 per cent.
" (average of 10 tests),	1.2 per cent.

SHEARING STRENGTH.

Ultimate (average of 7 tests),	 42,560	pounds.
" (average of 5 tests),	 43,100	"

These experiments were made at different times on two different sets of samples.

THE MOBILITY OF MOLECULES OF CAST IRON.*

By Alex. E. Outerbridge, Jr.

IT has been generally accepted as a fact that cast iron under the influence of repeated shocks becomes brittle, and will finally break under a blow which otherwise it would have withstood.

It will probably surprise metallurgists, therefore, to learn that experiment disproves the supposed fact and establishes exactly the opposite condition.

The result of about a thousand tests of bars of cast iron of all grades, from the softest foundry mixtures to the strongest car-wheel metal, enables me to state with confidence that within limits cast iron is materially strengthened by subjection to shocks or repeated blows.

It is very well known that the usual process of annealing castings —such, for example, as car-wheels—increases their strength by releasing cooling strains.

It is not well known, if known at all—prior to this announcement—that the molecules of cast iron are capable of movement (for they do not touch each other †) without the necessity of heating the castings, and they can thus re-arrange themselves in comfortable relation to their neighbors, and relieve the over-crowding near the surface of the casting, or, in more technical words, a molecular annealing may be accomplished at ordinary temperatures which will release the strains in the castings, precisely as does annealing by slow cooling in heated pits or ovens. Such a surprising statement should not be made without sufficient data to establish its correctness beyond cavil, since it is contrary to former belief, certain to be questioned and properly so.

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* Read at the Pittsburg meeting of the American Institute of Mining Engineers, February 20th, 1896.

† In order to comprehend the modern ideas of the nature of matter, we should try to realize that the molecules composing even the most dense solid substances with which we are familiar—such as gold, platinum, etc.—are not in contact and are free to move within certain well-defined limits. Lecture on "Matter," *Journ. Franklin Inst.*, September, 1885, v. 90, p. 184.

Before proceeding to give a record of the experiments which have been made, and which can be readily repeated by any one, a brief history of the origin of the first observation leading thereto may be interesting.

I noticed in the year 1883 (being at that time engaged in metallurgical work at a large car-wheel establishment), that chilled cast iron car-wheels rarely cracked in ordinary service after having been used for any considerable time; if wheels did not crack when comparatively new they usually lasted until worn out or condemned for other causes. No application was made of this observation at that time further than to institute a careful investigation of the condition of the annealing ovens when some new wheels were returned cracked, under the supposition that the wheels were not well annealed, and an equally careful revision of the iron mixture to ascertain whether the fault lay therein.

In 1894 a large number of "transverse test bars" (1 inch square, 15 inches long) accumulated in the foundry of Wm. Sellers & Co., Incorporated, and to expedite the cleaning of sand from their surfaces, they were all thrown into an ordinary "tumbling barrel," with other castings, and knocked about for several hours. When these test bars were broken upon the transverse testing machine and the records tabulated, I noticed, with surprise, that the average strength of the entire series was considerably higher than was usual with similar iron mixtures.

This difference was fortunately sufficiently marked to cause a careful inquiry, first into the condition of the testing machine, then as to the chemical composition of the metal in the bars; the machine was found in good order, the metal was normal. A card-pattern was then made upon which twelve test bars could be molded side by side in one flask and poured from one runner.

Six of these bars were placed in the tumbling barrel and the other six were cleaned of adhering sand with an ordinary wire brush; the twelve bars were broken upon the machine. ALL OF THE BARS WHICH HAD BEEN SUBJECTED FOR ABOUT FOUR HOURS TO INCESSANT BLOWS IN THE TUMBLING BARREL WERE STRONGER THAN THE

COMPANION BARS, the actual gain varying from 10 to 15 per cent.; this metal was soft foundry iron.

These tests were repeated on several consecutive days, with similar results, while various theories were being suggested and clews "run out" to detect the hidden cause of this strange fact.

One plausible explanation offered was that the rubbing of the bars together in the tumbling barrel slightly rounded the corners, and thus prevented a starting point for a "check" or break of the bar under the strain in the testing machine.

This theory was soon overthrown by tests. The corners of six bars were rounded by filing, the companion bars were not filed, all of the bars were cleaned with a wire brush and broken upon the transverse testing machine; there was no apparent gain in strength in the bars with rounded edges.

Round test bars (1⅛ inches diameter, 15 inches long,) were then poured from one ladle of iron; some of these were cleaned in the tumbling barrel, and all that were so treated proved to be much stronger than the companion bars, which were merely cleaned with a wire brush.

This process of eliminating false theories was continued, until finally a new explanation occurred to me, and simultaneously a convincing test of its accuracy suggested itself.

The explanation is indicated in the title of this paper, viz., "The Mobility of Molecules of Cast Iron" at ordinary temperature when subjected to repeated shocks.

The crucial test referred to was in subjecting six bars to 3,000 taps each with a hand hammer upon one end only of each bar. All of these bars so treated showed a gain in strength equivalent to the gain exhibited by bars which had been subjected to blows over the entire surface for several hours in the tumbling barrel.

Here was a new revelation of scientific interest to the metallurgist, and suggesting to the founder the possibility of annealing castings at ordinary temperature by availing himself of this molecular mobility, it also proves that he has for many years been unconsciously accomplishing this beneficial result—at least partially and irregularly—by tumbling small castings in a revolving barrel merely for the purpose of conveniently cleaning them from adhering sand.

Another interesting fact is incidentally brought out in this investigation, viz., that the strain caused by cooling and consequent weakening exists even in the smallest castings, where we would naturally expect that the cooling would be practically uniform throughout the section; also, that even in bars of uniform section, such as 1-inch test bars, the weakening by cooling strains sometimes amounts to more than 10 per cent. of the ultimate stress. Repeated tests show that ½-inch bars, in which the fracture is comparatively uniform to the eye throughout the section, are subject to the same law.

Other tests show that the comparative difference in transverse strength between bars which have been hammered on their ends, or otherwise subjected to the process of molecular annealing by vibration when cold, and companion bars cast in the same flask not so improved, depends, to a certain extent, upon the number and force of the blows, and to a still greater degree upon the grade of cast iron tested. For example:

1. Greater relative difference is found in hard mixtures (or strong iron) than in soft mixtures or weak iron.

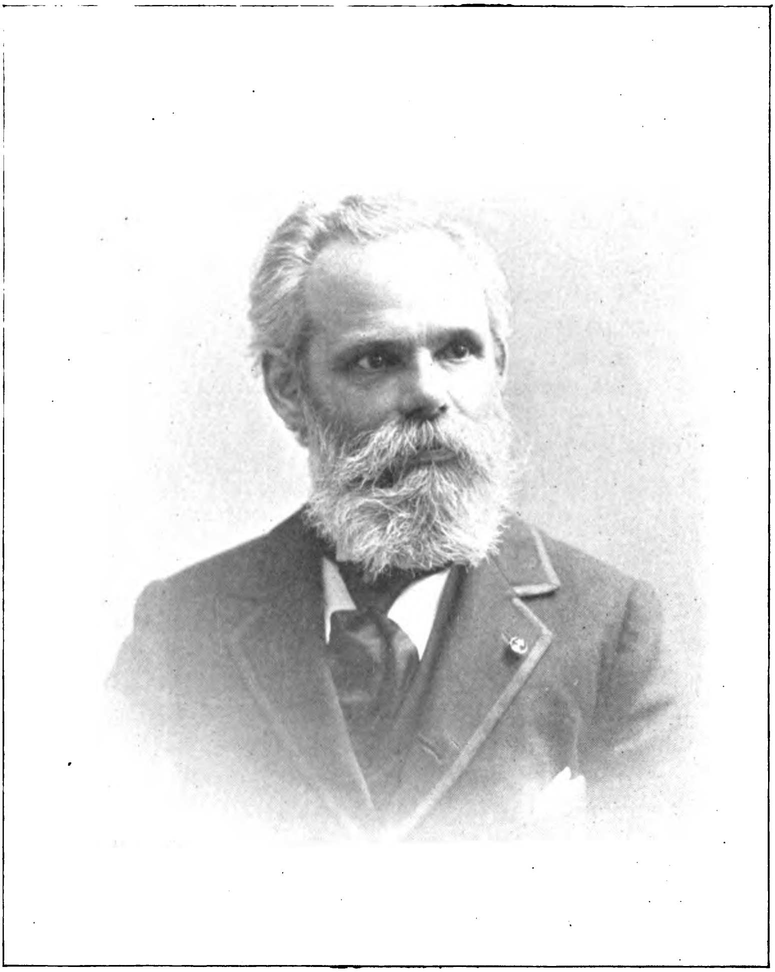
2. Greater relative difference is found in 1-inch bars than in ½-inch bars, and somewhat greater difference in 2-inch bars than in 1-inch bars.

IMPACT TESTS.

The foregoing achievements having been repeated sufficiently often to satisfy me of their absolute reliability (and really remarkable uniformity), a new series of tests was commenced for the purpose of ascertaining how many blows were required and approximately what force was needed to accomplish the desired object of relieving cooling strains. A new machine was constructed for this purpose, and light was soon thrown upon these questions, while still other important questions were suggested and answered by the use of the same machine.

The impact machine at first used was an old one, and consisted of a weight fastened to an arm swinging in a graduated arc. The friction of the pivot and the crude construction of the machine precluded certain or even approximately sure results as to the force of the blow delivered.

The new machine consisted of a frame or yoke marked in inches and a wedge-shaped weight adapted to the size of the bars to be tested, which was raised perpendicularly to any desired number of inches, and when released fell by gravity in free space, striking the bars in the centre between the supports, which were 12 inches apart. A 14-pound weight was adopted for testing 1-inch bars.



R. H. Thurston

DIRECTOR OF SIBLEY COLLEGE, CORNELL UNIVERSITY.

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Impact testing machines have long been used, and car-wheels are accepted or condemned upon tests made upon such machines. It has always been maintained that each blow of the "drop" weakened the casting, and the final blow was only a record of the residual cohesion remaining in the metal after previous blows had proportionately weakened it.

In the case of a thoroughly annealed car-wheel this reasoning may be sufficiently correct, but as applied to impact testing machines used for testing unannealed bars the argument is absolutely fallacious. The impact testing machine is itself a means of molecularly annealing test bars, as I will now proceed to demonstrate.

IMPACT EXPERIMENTS.

Six of the 1-inch square test bars, cleaned with the wire brush, were broken upon the impact machine by dropping the weight from a sufficient height to break each bar at the first blow. The six companion bars, also cleaned with the brush, were then, in turn, subjected to blows numbering from 10 to 50 each of the same drop weight, falling one-half the former distance, these blows being insufficient to break the bars. The weight was then permitted to fall upon each of these bars, in turn, from the height at which the six bars previously tested were broken on first blow. Not one bar broke. Two, three, six, ten, and in one case fifteen, blows of the same drop, from the same extreme height, were required to break these bars. In another similar case the weight was dropped once from the former maximum height, then raised by inches until four more blows, each being 1 inch higher than the last, were delivered before breaking the piece. Subsequent tests gave still greater gains in strength.

The next experiment with the impact machine was designed to test molecularly annealed bars from the tumbling barrel, in comparison with untreated companion bars, under one heavy blow. It was found that a blow of sufficient force to break the unannealed bars with one fall of the weight must be repeated from five to twenty times (depending mainly upon the nature of the iron mixture) to break the molecularly annealed companion bars.

By careful experiment, in the manner previously noted, the ultimate strength of the bars which had not been through the tumbling barrel could be increased by successive slight blows upon the impact machine to an equality with their companions.

The experiments here related in a running conversational narrative form a part of the daily records of the metallurgical work at the foundry of William Sellers & Co., Incorporated, Philadelphia, and the aggregate number tabulated is very large, indeed. All of the tests corroborate to the fullest degree the statements made, and they are susceptible of repetition and confirmation by any one interested in work of this character. They form part of a long series of investigations (extending over a period of 15 years) upon "the relations between the physical nature and chemical composition of cast iron." They have served to throw some light upon hitherto obscure phenomena in the design, construction, etc., of castings, and as it

Table I.—Strength and elasticity of test bars (A) of various kinds of cast iron, unannealed, and cleaned only with a wire brush, and (B) similar bars, molecularly annealed by repeated shocks in a tumbling barrel or by tapping with a light hammer.

A Cleaned with a Wire Brush. Results from Bars Unannealed.		B Results from Companion Bars "Molecularly Annealed."		Remarks.
Breaking Strain, Pounds.	Deflection, Inches.	Breaking Strain, Pounds.	Deflection, Inches.	
2,350	.13	2,850	.14	Close-grain iron.
2,025	.12	2,300	.14	Open "
2,125	.13	2,275	.14	" "
2,275	.13	2,400	.14	" "
2,525	.14	2,850	.15	Close "
2,175	.13	2,500	.15	Open "
2,100	.13	2,375	.14	" "
2,025	.12	2,300	.14	" "
2,775	.14	2,900	.15	Close "
2,150	.13	2,250	.13	Hammered on end of bar.
2,550	.14	2,925	.15	" " "
3,000	. .	3,200	. .	Round bars 1⅛ inches diameter.
3,000	. .	3,150	. .	Hammered on end of bar.
2,150	. .	2,450	. .	Round bars 1⅛ inches diameter.
2,100	.13	2,425	.15	Open grain iron.
2,100	. .	2,400	. .	Round bars 1⅛ inches diameter.
2,050	.12	2,400	.14	Open-grain iron.
2,875	.14	3,100	.15	Close "
2,175	.13	2,500	.15	Open "
2,150	.13	2,350	.13	" "
2,675	.13	3,000	.14	Close "
2,775	.14	3,300	.15	" "

is believed that they contain the germ of a new scientific discovery valuable in its principle to all workers in these fields, these brief notes are presented to the Institute of Mining Engineers in response to the invitation of its Secretary, and through the courtesy of the firm of William Sellers & Co., for whose benefit and at whose cost they were primarily made.

In conclusion, it should perhaps be stated, to avoid the possibility of misunderstanding, that molecular annealing of cold cast iron by successive slight shocks differs from annealing by heat, in that it has no power to change the condition of carbon in the casting or to alter the chemical constitution in any way; all that is claimed is that every iron casting when first made is under a condition of strain, due to difference in the rate of cooling of the metal near the surface, and that nearer the centre, and also to difference of section; that it is possible, and practicable, to relieve these strains by tapping repeatedly the casting, thus permitting the individual metallic particles to re-arrange themselves, and assume a new condition of molecular equilibrium.

The large number of tests made and the remarkable uniformity of results obtained permits me to make these statements with full confidence that their repetition, even under less favorable conditions for accurate observation than I have enjoyed, will serve to convince others of their correctness, and perhaps to establish a new law of physics of cast iron.

A few practical deductions of universal application may be drawn from these observations:

1. Castings, such as hammer frames, housings for rolls, cast iron mortars or guns, which are to be subjected to severe blows or strains in actual use, should never be suddenly tested to anything approaching the severity of intended service.

Quantitative tests made upon the impact machine prove that the molecules of cast iron rearrange themselves under reasonably few shocks, so that it is perfectly practicable to molecularly anneal such castings when cold. Pulleys, and indeed all castings, are subjected in every-day service to this process of molecular annealing, and old castings are, therefore, more reliable than new ones, unless misused.

It is not impossible that the same law applies to steel castings, and, perhaps, to all metal castings, and in testing new guns each preliminary small charge of explosive material, subjecting the castings to comparatively moderate shocks, enables the gun to relieve itself of internal strains, and eventually to withstand with safety shocks which would have destroyed it without this precautionary measure. This, however, is mere theory and must not carry the weight of the arguments regarding cast iron, which are clinched by a thousand actual tests.

2. Strong iron castings, and castings of irregular section have greater initial strains than soft iron castings, or castings of comparatively uniform section, and it is, therefore, more important to subject such castings to gradually increasing shocks, until the strains are relieved by the movement and rearrangement of the molecules.

TABLE II.—Results of tests with Impact Testing Machine of cast-iron bars. (Bars marked A cleaned with a wire brush. Bars marked B “ molecularly annealed.”) (Weight of drop, 14 pounds);

		Fracture.	
A,	1 drop of 13 inches broke the bar,	Open	Grain
B,	8 drops “ 13 “ “ “ “	“	“
A,	2 “ “ 14 “ “ “ “	“	“
B,	9 “ “ 14 “ “ “ “	“	“
A,	2 “ “ 14 “ “ “ “	“	“
B,	14 “ “ 14 “ “ “ “	“	“
A,	2 “ “ 15 “ “ “ “	“	“
B,	15 “ “ 15 “ “ “ “	“	“
A,	3 “ “ 15 “ “ “ “	“	“
B,	8 “ “ 15 “ “ “ “	“	“
A,	2 “ “ 15 “ “ “ “	“	“
B,	7 “ “ 15 “ “ “ “	“	“
A,	3 “ “ 13 “ “ “ “	Close	“
B,	4 “ “ 15 “ “ “ “	“	“
A.	2 “ “ 13 “ “ “ “	“	“
B,	10 “ “ 13 “ 5 of 15 inches, 5 of 17 inches, 3 of 18 inches, broke the bar,	“	“
A,	1 drop of 14 inches broke the bar,	Open	“
B,	20 drops of 13 inches and 3 of 14 inches, broke the bar,	“	“
A,	3 drops of 13 inches broke the bar,	Close	“
B,	15 “ “ 14 “ “ “ “	“	“
A,	8 “ “ 12 “ “ “ “	“	“
B,	50 drops of 12 inches, and 10 drops of 15 failed to break the bar.		

NOTE.—The last bar, after withstanding these blows, was broken upon the transverse testing machine at a strain of 2,975 pounds.

The tables appended hereto show the results of tests for transverse strength of test bars of different sections and widely different grades of iron which have been subjected to this process of molecular annealing, and also tests made upon the impact machine with test bars cast in the same molds.

Desiring to avoid unnecessary duplication of figures, a few individual tests only are here tabulated; but they represent the average of probably a thousand records.

The largest comparative gain, shown in the first table, in transverse strength, of companion bars of 1-inch section, is 525 pounds (see last line), or very nearly nineteen per cent.

It is evident, even without plotting all the tests, that they would show a gradually ascending curve having direct relation, first, to the character of the alloy of iron; second, to the number of blows given, up to the point where strain is relieved, beyond which an increased number of blows does not increase the strength of the bar. Furthermore, it may be noted that the tests with the impact machine prove the existence of a similar law in relation to the ability to resist sudden and severe shocks.

Similar observations apply to the tests recorded of ½-inch and 2-inch bars. All of the 2-inch bars were broken upon the testing machine of Messrs. A. Whitney & Sons by their operator, who was at first ignorant of the object of the tests. Subsequently similar tests were made by that firm with their car-wheel iron, and identical results were obtained by them.

TABLE III.—Results of test of 2-inch cast-iron bars upon A. Whitney & Son's Testing Machine. (Bars marked A cleaned with a wire brush. Bars marked B molecularly annealed):

	Breaking strain lbs.	Grade of Iron
A,	20,400	Close grain
B,	21,600	" "
A,	13,600	Open "
B,	15,800	" "
A,	14,000	" "
B,	14,800	" "

Other experiments have suggested themselves in the course of this investigation, and my paper, therefore, is not presented as an exhaustive, but as a tentative treatment of this interesting, and, I believe, novel line of research, which is not devoid even in its present stage of some practical application.

PICKINGS FROM THE PRESS

THE SPECIFIC GRAVITY OF CEMENT.

WITHIN the last few years the determination of the specific gravity of hydraulic cements has passed out of the category of methods of assay to be occasionally used, into that of modes of testing habitually employed in the evaluation of this class of constructional material. In thus changing its status this test had to encounter the rivalry of one already well established, and deemed preferable by many, viz., the determination of the weight per bushel.

One great factor in the contest between the two methods consisted in the increase in fineness of all ordinary cements, arising both from the growing stringency of the demands of foreign markets and from the more exacting requirements of engineers in this country. This factor was wholly on the side of the determination of specific gravity instead of weight per bushel. Consumers were quick to recognize that a finely ground cement necessarily weighed less, other things being equal, than one which was coarsely ground, and, moreover, that it was not easy to make a satisfactory sliding scale, and form a standard of relation between fineness and weight per bushel. At this juncture, appreciation of the fact that the specific gravity of a cement is unaffected by the degree of fineness, led to a general abandonment of the use of weight per bushel, and to the adoption of the determination of specific gravity in its place. The upshot at the present time is that the specific gravity of a cement is generally conceded to give all the information concerning the quality of a cement which was afforded by the former method of testing, and in addition to give certain other indications of its own. When properly carried out, the experimental error is but small, and the results obtained require fewer corrections in order to afford a consistent meaning.

Whether the causes just sketched have been at work in France as well as here, is uncertain, but a similar effect is at least apparent. In one of the monumental volumes recently issued by the Commission des Methodes d'Essai des Materiaux de Construction, the whole subject is discussed with much lucidity. It appears that our neighbors consider themselves behind their competitors in the adoption of the specific gravity test, and are anxious to bring it into regular and intelligent use. To this end the requisite precautions are described, and may be found of value to those interested in cement.

The usual method of taking the specific gravity of cement differs in no essential respect from that commonly adopted for other substances; it is in the details of working necessitated by the nature of the material that special care is required. In all cases a known weight of cement is allowed to displace a measured volume of some liquid; but the variations of manipulation designed to make the operation accurate, simple, and rapid are numerous. In the first place, it is obvious that the liquid displaced by the cement cannot well be water, inasmuch as hydration of the cement would occur during the process, and a consequent alteration of its volume would result. The use of some liquid free from water, and neither very volatile nor hygroscopic, must therefore be adopted. Those mentioned by the French Commission are benzine—the coal tar product commonly called benzole—and petroleum spirit. Both are somewhat more volatile than is desirable, and spirit of turpentine, thoroughly dried by standing over quicklime, is probably preferable to either. Absolute alcohol is much too hygroscopic for convenient use, and kerosene—ordinary "paraffine-oil" for domestic lighting—is apt to contain light fractions which are open to the same objection as that urged in the use of petroleum spirit. Whatever liquid be ultimately chosen, it must be mobile enough to allow the ready escape of bubbles of air imprisoned in the cement.

With regard to the degree of accuracy with which the specific gravity of a cement must be determined in order to yield useful results, it may be said that very rough figures will suffice to relegate a product, of which the origin and history are unknown, into its proper class. Thus a specific gravity of about 3.15 at once stamps the cement possessing it as a true Portland cement. In like manner, blast furnace slag has a mean specific gravity of 2.60, and admixture of any serious proportion with a true Portland cement would be at once indicated by the low specific gravity of the product.

It is interesting to note that, as stated above, the application of the specific gravity test is neither so common nor so well understood in France as it is here. The very committee appointed to report on the matter regrets that the determination of the specific gravity cannot be used for detecting an under-burnt cement, while in the same sentence quoting figures which easily suffice for that purpose. A wellburnt cement was found to have a specific gravity of 3.154, and one which was under-burnt gave the figure 3.108. Seeing that with nothing more than ordinary skill and care the specific gravity of a cement can be determined with accuracy to 0.005, and that the difference here noted is nearly ten times as great, it is evident that the conclusion of the committee is invalid. As a matter of practical fact, the determination of the specific gravity of cement is used freely in this country to distinguish between well and under-burnt cements. With obsolete apparatus and clumsy manipulation, the records were doubtless inconveniently close; but with modern apparatus and trained hands, the feat is of the simplest.

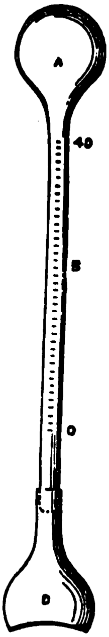

Fig. 1.

Attention is very properly directed to the influence of water and carbonic acid absorbed by the cement from the air upon its specific gravity. A single per cent. will make a sensible difference, and judgment of the exact meaning of the specific gravity of a given sample is much aided by having record to this effect. The change produced by aeration is in the direction of lightening the cement, the reason being that the hydrated and carbonated compounds, formed on exposure to air, are of lower specific gravity than the cement fully clinkered and free from all moisture as it comes from the kiln. An account is given of the commoner forms of apparatus used for the determination of specific gravity of cement, but as these are well known, a description in these columns would be superfluous.

Two forms of recent design, and both of French origin, merit special notice. The first is one due to M. Candlot, and is shown in Fig. 1. It consists of a flask, C, into the neck of which is ground the glass tube, B, bearing a bulb, A, at its upper end. The apparatus is used in the following way:

Benzine, or other appropriate liquid, is poured into the bulb, A, separated altogether with the tube from the flask, C, in such quantity that on re-connecting the apparatus and bringing it into its normal position the flask, C, is filled, and the liquid stands at or about zero on the graduated tube. The height of column is read, the apparatus is again inverted, and the benzine allowed to flow into the bulb, A, so as to permit of the removal of C and the introduction of a known weight of cement. The tube and flask are joined once more, and the whole well shaken, to expel air-bubbles from the cement and to cause it to displace its true volume of liquid. The height now reached by the liquid in the graduated tube is the measure of the volume of a known weight of cement.

Before the second reading it is, of course, necessary to bring the whole apparatus to the same temperature as that which it had at the time of the first reading. Immersion in a water-bath allows of this adjustment. The process thus performed is less operose than it sounds, and gives fairly exact results. Expulsion of air-bubbles is tolerably easy when dealing with Portland cement, which is not unusually finely ground, but with hydraulic limes it is difficult.

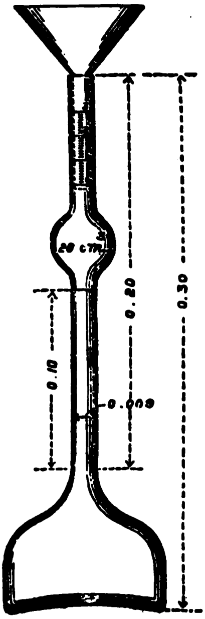

FIG. 2.

The second apparatus is one designed by M. H. Le Chatelier, and is altogether better than the foregoing. It has been officially adopted by the Commission. As shown in Fig. 2, it consists of a flask of a capacity of about 120 cubic centimetres, and having a neck some 20 centimetres in length, half-way up which is a bulb having a capacity of 20 cubic centimetres. Above the bulb the tube is graduated for a length corresponding with a capacity of 3 cubic centimetres, the divisions being 0.1 cubic centimetre. The diameter of the tube is about 9 mm.—say one-third inch. The instrument is used in the following way:

The flask is filled with benzine to the mark just below the bulb, and 64 grammes of the cement to be tested are gradually introduced through the funnel shown at the tube. By using a funnel reaching nearly to the upper part of the bulb, risk of the cement blocking the upper narrow graduated tube is avoided. As the level of the benzine rises to the lowest point of the graduations the cement is introduced cautiously, little by little, until the first graduation is reached. The volume of the cement in the flask is then 20 cubic centimetres, and its weight is ascertained by deducting that, or the portion left, from the original quantity of 64 grammes. Conversely, the whole quantity can be inserted, and the volume over and above 20 cubic centimetres read off on the upper graduated tube.

The figures quoted are for cement such as true Portland, with a specific gravity greater than 3.0. For other hydraulic cements of lower specific gravity smaller weights can be taken. The flask is kept in a vessel of water throughout the operation, and errors due to fluctuations of temperature are thus avoided. It is stated that air-bubbles are completely expelled from the cement as it flows down the long tube below the bulb, without need arising for shaking the apparatus.

As far as can be judged without actual use, the little instrument is well devised, but its readings would be scarcely close enough for exact work. Thus, each division—0.1 cubic centimetre—on the graduated tube corresponds in the case of Portland cement with a difference of specific gravity of 0.015, a possible error which is unduly great. It is certainly doubtful whether the absence of air-bubbles can be assured by spontaneous passage of the cement down the column of liquid in the tube below the bulb. Cement is particularly tenacious of its enclosed air, and will carry such air down through a long column of liquid with surprising ease. Nothing but diligent tapping and shaking will dislodge bubbles thus enclosed, and eliminate the air due to their volume being credited to the cement.

Apart from these details—which are matters on which friendly criticisms may be offered without imperiling international good-will—the report is altogether clear and excellent, and goes to prove that if there has been any delay on the part of French experts to adopt a method of testing which is now generally approved in this country, that delay is in a fair way to be forgotten by our appreciation of the keenness and clarity with which they have now set themselves to decide upon and introduce a trustworthy standard method and apparatus.—*The Engineer* (London).

RECENT BOILER-PLATE TESTS.

Some interesting results have been obtained by the Paxton Rolling Mills, of Harrisburg, Pa., on tests of boiler-plates for 20 Russian locomotives now building at the Baldwin Locomotive Works. The steel had to show a tensile strength of 35 to 42 kilos. per square millimetre (about 50,000 to 60,000 pounds per square inch), and an elongation in 8 inches of 25 per cent., both longitudinal and transverse. With the exception of 20 plates ⅝ by 87 inches wide, the material varied from ½ to ¾ inch thick by 74 inches wide and under. Of the 104 plates rolled, three failed in tensile and one on gauge. In elongation the remaining 100 plates averaged 27.46 per cent. in the longitudinal direction, and 27.90 per cent. in the transverse—the latter result not generally looked for. All the steel slabs were furnished by the Pennsylvania Steel Company, made in open hearth basic furnaces, and showed an average analysis as follows: Carbon, 0.165; phosphorus, 0.014; manganese, 0.37, and sulphur, 0.27.—*The Iron Trade Review.*

TENSILE TESTS OF CAST STEEL.

Below is published a table showing the result of tensile tests of fifteen specimens of cast steel. These castings were made by the American Steel Casting Company, of Thurlow, Pa., for use in the Buffington-Crozier disappearing carriages, being built for the Ordnance Department of the United States Army. The results would be remarkable for the best forgings, and for steel castings they are considered by experts as really extraordinary. The figures published are duplicates of those which appear on the report of Captain D. A. Lyle, Ordnance Department, United States Army; and Captain Lyle, in signing the report, offers his congratulations. The results here shown cover castings produced from five different heats, indicating remarkable uniformity. The length of stem of the test piece was two inches, and in each case the fracture is noted as silky, and all of the specimens were accepted.

Steel Castings made by the American Steel Casting Company, for the Ordnance Department, U. S. A.—Tensile tests.

Elastic limit. Pounds per square inch.	Tensile strength. Pounds per square inch.	Elongation after rupture. Per cent.	Reduction of area after rupture. Per cent.
30,000	67,000	28.8	46.3
32,000	68,500	29.0	47.8
30,500	67,000	30.6	52.8
30,500	70,500	28.8	41.0
33.500	72,500	27.2	42.5
30,500	65,500	29.8	44.9
30,000	65,000	30.5	54.1
32,000	69,500	27.0	48.6
29,000	65,000	26.0	50.0
30,000	65,000	30.2	51.1
30,000	68,500	28.3	42.2
30,000	65,500	26.0	50 9
33,500	68.500	34.3	43.7
29,500	66,500	29.2	48.0
32,500	69,000	28.0	41.9

—*The Railway Review.*

THE HOLDING POWER OF LAG-SCREWS.

Some time ago I made a few experiments on the holding power of lag-screws, the result of which is given below. The holes were bored by a common carpenter's bit in 8-inch square logs, and the screws put in same as would be in common practice, and they were pulled out by the use of an Olsen testing-machine:

Diameter of screw.	Diameter of bit.	Length of thread screwed into the wood.	Kind of wood.	The load at which screw pulled out.
⅞ in.	⅝ in.	3 in.	Spruce	5,900 lbs.
⅞ in.	11-16 in.	3 in.	"	5,900 lbs.
⅞ in.	¾ in.	3 in.	"	6,000 lbs.
⅞ in.	¾ in.	5 in.	"	9,000 lbs.
⅞ in.	¾ in.	5 in.	Chestnut	9,500 lbs.
¾ in.	⅝ in.	4½ in.	Spruce	7,000 lbs.
¾ in.	⅝ in.	4½ in.	Pitch pine	8,300 lbs.
⅝ in.	½ in.	4 in.	Spruce	6,000 lbs.
½ in.	⅜ in.	3½ in.	"	3,500 lbs.
⅜ in.	5-16 in.	2 in.	"	1,900 lbs.
¼ in.	3-16 in.	1 in.	"	700 lbs.

The experiment seems to indicate that there is no advantage in using too small a bit when boring holes for lag-screws. For instance, the ⅞ screw required fully as much force to pull out from a ¾ hole as it would take to pull out of a ⅝ hole, although it is a great deal easier to put the screw in after a ¾ bit than it is after a ⅝ bit, and it is certainly work spent in the wrong direction to use a bit smaller than the core of the screw.

By splitting the block and examining the wood around the screws it will be found that when too small bits are used the fibres in the wood around the screws are crushed and destroyed, but when the right size bit is used the thread in the wood around the screw looks clean-cut, the texture of the fibres is pressed, and the fit in the wood on the screw resembles the appearance of a nut on a bolt.

When the ⅞ screw was screwed into a ¾ hole its full length of thread, or 5 inches, it required a force of 9,000 pounds to pull it out; therefore it is safe enough for any temporary job under a steady stress to lift one ton in a ⅞ lag-screw, as this gives about 4 as factor of safety in pulling out of the wood, and there is no danger of pulling off the screw itself, because at the place of the core where it could break it is about inch in diameter = 0.37 square inch area.

Assuming ultimate tensile strength to be 50,000 pounds per square inch, the breaking load would be 50,000 × 0.37 = 18,500 pounds; thus there is no danger at all of the screw itself breaking for a load of a ton.—*P. Lobben in American Machinist.*

MORTARS AFFECTED BY FREEZING.

It appears to be ascertained as a fact, based on more than six thousand recorded results, that Portland cement mortar suffers no surface disintegration under any condition of freezing, but that in most cases its strength is reduced, in some cases by as much as 40 per cent. Rosendale cement is disintegrated when exposed to frost while setting, and its cohesion may be entirely destroyed by immersion in water, which becomes frozen around it. Salt water prevents this disintegration to a large extent, but seems to have an injurious effect upon the strength, and the cement below the disintegrated surface is stated to be increased in strength when the Rosendale cement is used. A mixture of a natural rock cement and of Portland cement is found to give very satisfactory results, as its surface does not disintegrate, and its strength is increased by the freezing. Portland cement is injured less proportionately as the percentage of the cement in the samples is reduced. Again, though lime mortar is ruined by alternate thawing and freezing, fairly good results may be looked for in the case of brick masonry when the mortar is kept frozen for some time after laying.—*The Railway Review.*

ENGINEERS know that the strength of wrought iron at 60° and 320° is practically constant, while at 30° the strength was greater; but until Professor Dewar's recent researches they could never have conceived that when immersed in liquid air at a temperature of –320° the strength of iron wire would be raised from thirty-four tons to sixty-two tons per square inch. The chemical constituents of iron and steel do not change, but the molecular arrangement and intercrystalline cohesion must change, and it is to mathematical investigation and laboratory work, rather than to practical engineering that we must look for an elucidation of the process.—*Engineering Mechanics.*

LETTERS TO THE EDITOR.

This department is set aside as an open door for communications upon all subjects pertaining to the physical properties of the materials of construction. We solicit letters from the colleges, private and governmental laboratories, both at home and abroad, and from all those interested in the field which we represent. It is desired that this department shall be the means of bringing forth and circulating amongst engineers and architects the knowledge gained in these various laboratories. And we shall hope to have it well filled with testing-room kinks, and practical facts of permanent value.

PRESS PRESSURES.

Editor Digest:—In testing dies which are mounted in punching, forming, and coining presses, it is often desirable to know the pressure exerted through them, not only at its maximum point, but at other stages during the descent of the ram. For this, as far as the writer is aware, no special device has ever been built, the few experimenters in this line having had recourse to a pair of dies mounted temporarily in an ordinary testing-machine.

It is much to be desired that a practical "testing-bolster" should be contrived which could be placed upon the bed of any press, and upon which ordinary dies could be mounted. For the majority of the work a device in the form of a flat plate, not more than four inches thick, one foot wide from front to back, and of any reasonable length between one and four feet, would be immensely useful. It should have a range for measuring presses from, say, 100 to 200,000 pounds, and should preferably be a recording instrument, capable of making a chart similar to the diagram of a steam-engine cylinder, the ordinates of the curve representing the pressures, and the abscissæ the time, or, what amounts to the same thing, the amount of ram-descent during the time in which actual work is done.

The writer has contrived several methods for accomplishing the above purpose, but has never yet found any which seemed as if it would satisfactorily (and *cheaply*) meet all the conditions. The actual building of the device is therefore in abeyance, for the present, unless indeed somebody else has taken it up. The chief difficulties in the way are the small available space and the necessity of weighing so heavy and so greatly varying a pressure anywhere over a broad, flat space. Were it balanced in the centre, the task would be easier, as it also would for a small range of pressures.

OBERLIN SMITH.

BRIDGETON, N. J.

LENGTH OF REDUCED SECTION *versus* ELONGATION OF TEST SPECIMENS.

Editor Digest :—Answering your inquiry, asking the writer's opinion on the effect of lengthening the distance between the necks of test pieces for tension tests, the writer would say that the greater the distance between the necks, the larger will be the percentage of elongation in each inch of test piece after the piece has been subjected to the breaking strain.

From the number of tests made in the Physical Laboratory of the Phœnix Iron Works, the truth of this statement has been demonstrated beyond doubt.

The writer personally conducted a series of tests, in which four test pieces were cut side by side from the same plate, from three different plates, making in all twelve pieces. One piece from each plate was necked to the length of 2″, one piece from each plate to 8″, and one to 12″, while the fourth piece from each plate was planed to the width of the necked section in the other test pieces. After breaking, it was developed that the piece 2″ long had stretched on an average of about 36 per cent., while the 2″ adjacent to the fracture in the 8″ long piece had stretched fully 37 per cent., in the 12″ piece the 2″ section had stretched over 38 per cent., and in the piece which had not been necked the elongation in a similar length had been over 39 per cent. It was also noticed that the elongation in 8″ of the two long pieces was proportionately more than in the pieces which had been necked to 8″.

At first sight this is paradoxical, but on reflection it seems perfectly clear that the molecules of the long sections have more time to adjust themselves to the ever-changing conditions of the test pieces while being pulled, while the shorter pieces, being broken in so much less time, have very much less time to accommodate themselves to the conditions.

I do not know that these results have developed anything which has not been known, but in view of the important relation existing between the percentage of elongation and the ultimate strength, they are not only important, but interesting as showing the effect of the length of the piece upon the elongation, as developed by testing in a standard testing machine.

It is a general rule that soft steel will develop a much greater elongation than steel of a higher tensile strength, and it therefore follows that the better of two steels is the one that will show the higher ultimate, if the percentage of elongation is the same as in the softer steel; and, similarly, that if the ultimate strength of two steels is the same, that which shows the greater elongation is the better.

Nearly all specifications are based upon the results of previous tests, and it is manifestly unfair to the manufacturer to expect steel to develop in a necked section 8 inches long the same elongation that was at some previous time developed in 8 inches of a section 12 inches long. On the other hand, if a specification has been based upon the elongation as developed in a test specimen necked to a length of 8 inches, the results obtained from a section 12 inches long, or longer, are clearly unreliable for comparison.

As existing specifications have, for a large part, been written by theoretical but impractical engineers, and are largely influenced by personal bias and opinion, and do not represent the thought of the persons best able to define what should be required in steel or iron for its various uses, viz.: the manufacturers; the writer would suggest that the editor of the DIGEST should take up the question now being agitated by several of our most prominent steel manufacturers, and urge the adoption of a uniform specification for quality of material in a convention in which the manufacturer should be represented. The question of length of test piece should be definitely settled by such a convention, for by this means only can uniformity of results be obtained.

ED. HAUPT.

PHŒNIXVILLE, PA.

NOTES AND COMMENTS.

ENGINEERS all over the country will be interested in learning of the discovery of a new method of conducting tests when the strength of the specimen to be tested exceeds the capacity of an available machine. Since the strength of a material is in direct proportion to its area, and the area is in direct proportion to the diameter, it is hardly the work of a moment to ascertain the approximate number of square inches in a test specimen. We say "approximate" because the exact ratio of the diameter of a circle to its circumference is not known, although it is believed that the ancient Egyptian philosophers were in possession of the secret. Ahmes, a scribe of King Ra-a-us, in his *Papyrus Rhind*—the oldest mathematical book in the world—gives a transcript of a treatise written about 2,500 years B. C., in which was a rule for finding the area of a circle. Another solution was claimed by Hippocrates, the geometrican of Chios, 500 B. C. The Babylonians, also, had a rule, but it was not until Euler introduced the symbol π to represent the ratio of the circumference of a circle to its diameter, and Archimedes proved it to be less than 3.1-7 and greater than 3.10-71, that the ratio of 3.1416+ was accepted, and the problem brought within the scope of the ordinary machine shop. But out of the hundreds of known rules for squaring the circle, there are none quite so startling as the one recently evolved by a nineteenth-century engineer and inspector in the employ of one of the prominent English Steamship Insurance Companies, who, having occasion to test the tensile strength of a 1¾ inch chain cable when the largest available testing machine would only pull 1½ inch diameter, first broke a one-inch chain and then a three-quarter inch chain, added the results together, and handed in his report.

If the resolution providing for an investigation into the Bureau of Ordnance of the Navy, recently introduced before the Senate by Senator Chandler, and which has excited such interest and comment in navy circles, is accepted, and the investigation conducted with the thoroughness the resolution calls for, many facts are certain to come to light which, it is believed, will seriously effect the integrity of the Navy Department. In Washington it is current talk that while every large railway corporation and industry interested in the purchase of material by contract only accept such after rigid inspection by high-class experts, the Navy Department has, for years past, assigned to this duty ensigns and lieutenants with no practical knowledge of either the materials or their manufacture. In our own experience with Government Inspectors, both with experienced men and those just assigned to the duty, we have yet to find one who, though not possessed of an accurate knowledge of the manufacture of the materials, is so lacking in common intelligence as to make such an exhibition of his low-classness as reported in the test of chain cable cited above, which was conducted by one of the so called high-class experts.

A correspondent writes us that he is very much pleased with the initial number of THE DIGEST, and assures us that the publication will meet with success, but suggests that we omit all such unscientific matter as appears upon page sixteen. While we feel that his criticism is entirely fair, and are very grateful for the friendly spirit in which it is given, we think he is rather hard on one of our tender years, and should appreciate that so sudden an appearance of a Black Cat was likely to drive any poor devil of an editor to the point of making fun. And wherein lies the harm? Surely it is strengthening to one's nerves to indulge in a bit of innocent foolery as an appetizer before swallowing something heavy. It is told of Abraham Lincoln that he frequently interspersed humorous anecdotes while discussing the gravest affairs of State. With this example before us, we feel exonorated for introducing matter which, to the serious-minded, may appear frivolous and out of place.

The Fifth International Congress for the unification of the methods of testing materials of construction was held at Zurich in September, 1895. Nearly five hundred members took part in the deliberations, either by correspondence or by actual presence, six of whom were from the United States. On the third day the work of the American Society of Mechanical Engineers was fitly recognized by its representative G. C. Henning, of New York, being called to the place of honorary chairman. A large number of valuable papers were read and discussed. Professor L. de Tetmajer, of Zurich, was elected President of the Association for the year 1896 and 1897, and an executive committee, composed of Professor Belelubski, of St. Petersburg; Councillor Berger, of Vienna; Professor Martens, of Berlin, and Baron Rochemont, of Paris, was appointed. Authorities on the subject of testing and organized societies are admitted to the Association on their application; others must be proposed in writing by two members. Each member agrees to contribute in proportion to his means to advance the aims of the Association. Propositions for membership should be directed to the President. An annual fee of five francs, four marks, or one dollar, is paid by each member, and he receives the journal of the Association at a reduced price. The affairs of the Association are managed by the president and executive committee, aided by an advisory committee of delegates to the Congresses which are held every two years. A movement is on foot to issue an international review which will doubtless appear as a part of the journal of the Association. The Sixth Congress will be held at Stockholm in 1897, and the Seventh at Paris in 1900. It is to be hoped that the number of American members of the Association may be largely increased, so that a full presentation of American methods of testing may be made at those Congresses. Uniformity in testing is necessary for the purposes of comparison; much good work has been already done in this direction by the International Association, and much more will result from its future deliberations.

All practical steel plate and rolling-mill owners will join us in entering our protest against the adoption of a standard test specimen of the form recommended in the amendments recently submitted by the committee of the American Steel Manufacturers to the Board of Supervising Inspectors of Steam Vessels at Washington. The specifications provide that the test-pieces shall be prepared in the form shown in Fig. 1, which, every practical engineer will see at a glance, is a very difficult and expensive shape to make. When it is considered that some of the large mills pull their tests at the rate of sixty per hour on a single testing machine, it will be appreciated that the cost of preparing the specimens is a very important item in the expense of maintaining a laboratory. Sixty specimens per hour is, we think, far too fast to obtain reliable results, giving too high a tensile strength and destroying the elongation, but to be able to pull even half this number per hour, requires the use of the most modern appliances for preparing the specimens. Before the introduction of special tools for this purpose, it was not unusual to see as many as six shapers running to supply one testing-machine. Test pieces prepared on a shaper have both edges parallel throughout their length, but these, in turn, as shown by Mr. Edward Haupt, of the Phœnix Iron Co., have too great an elongation. In later practice various other more rapid methods have been tried, among which are the Newton Saw and the Ingersoll Planer. The saw was never destined to set rivers on fire, and soon dropped into oblivion, while the Ingersoll Planer, though a large and powerful milling machine, well adapted to a wide range of usefulness and capable of rapid work, possesses the disadvantage of only milling one side of a row of specimens at a time. The newer machines are designed on the rotary planer principle, and finish both sides of a row of test pieces simultaneously. The machines are fitted with two heads, each carrying from eight to twelve tools. The shape of these tools fix, of course, the shape and size of the fillet in the test specimens, and since the tools, to obtain a smooth finish in the test pieces, must be dead in line, it is necessary to grind them after they are set in the heads. By using tools ground to form a specimen the shape of Fig. 2, this grinding is reduced to a comparatively simple operation. They can, however, be more readily ground to give the form shown in Figs. 3 and 4, but to produce the test piece shown in Fig. 1, requires the use of an axie-mill four inches in diameter, and the slow process of feeding the cutter by hand until it reaches the required depth, this tedious

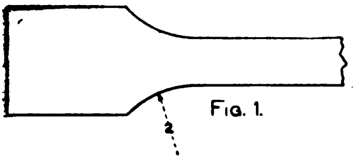
Fig. 1.

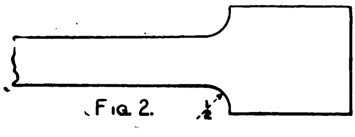
Fig. 2.

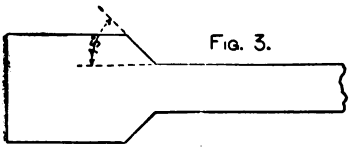
Fig. 3.

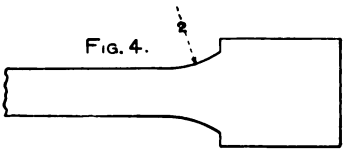
Fig. 4.

task only being obviated by the additional expense of a special grinding machine to round the corners of the cutter, so as to permit cross-milling. Why, in these times of systematic inspection of material by "high-class experts," manufacturers should be obliged to incur the heavy expense of preparing test specimens in the form proposed by the committee, when other and cheaper forms give precisely the same results, and curtail the tax on the time and patience of the Government Inspectors who are obliged to remain idle while the test pieces are being prepared, is, to us, an unexplainable mystery.

In another part of this issue appears a report on a series of tests on paving bricks to determine the compressional strength and the amount of absorption. Considering the immense growth of the paving-brick industry during the last ten years, it is important that the testing laboratories of the country should devote some attention to the qualifications of a first-class paving brick. The engineering societies should prescribe a standard method of testing paving bricks, for at the present time the methods are so at variance that we have no means of comparing the relative merits of paving material. The most important tests that can be made are the tests for compressional strength and the amount of moisture absorbed; the former gives us a definite notion of the brittleness and elasticity, as well as the compressional strength; the latter enables us to select a brick that will not disintegrate in freezing climates. The record of tests presented by Professor Anderson includes twelve of the most important and reliable paving bricks made in this country, and the illustrations of the fractures form an important feature of the article, for by these fractures we are able to determine, to a large extent, the homogeneity of the paver, and by this means the care with which the material is ground and worked will be apparent.

In a recent letter to the *Engineering News*, Booth, Garrett & Blair give the following rule for determining the proper proportion of water in mortar mixtures, which, they say, has been adopted in their laboratory with entirely satisfactory results. First determine by pat tests the proper percentage of water for the neat cement, then reckon at 7 per cent. the amount of water required for the sand. Thus, if the neat cement takes 25 per cent. of water, the proper amount for a three to one mortar would be as follows:

1 part cement at 25 per cent.,	.25
3 parts sand at 7 per cent.,	.21
4 at 11½ per cent.,	.46

Or for a two to one mortar of the same cement as follows:

1 part cement at 25 per cent.,	.25
2 parts sand at 7 per cent.,	.14
3 at 13 per cent.,	.39

This rule gives proportions of water which are entirely satisfactory for ordinary commercial mortar sands; a little less can be used with standard test sand. For rammed work we are confident these proportions should not be exceeded; if they are, the mortar will be "sloppy." For work which is laid with a trowel, more water is advantageous. The rule is also quite satisfactory for concrete, if the stones are moistened before they are added to the mortar.

The history of the designing and constructing for the United States Government, by Mr. A. H. Emery, of the famous *one million pound testing machine*, which has been in constant use at the Watertown Arsenal for fifteen years, is well known to physicists and engineers. The machine differs so radically in principle from all other testing machines that it has created world-wide interest, not only on account of its great capacity, but also from its extreme delicacy and sensitiveness in operating, being practically as sensible of small variations of stress when loaded to its full capacity, as when merely tested under the weight of the beam itself. When it was originally announced that friction under heavy loads was so completely neutralized that a practically frictionless testing machine resulted, the statement was received with incredulity, then with wonder, but is now accepted as a demonstrated fact. The chief objections that have been raised to this machine are the first cost and the slowness of action as compared with testing machines of the usual construction. While it is true that the design of the machine renders it, necessarily, somewhat costly to construct, and while it is also true that the Watertown machine is not as well adapted to rapid commercial work as to original scientific investigation — for which purpose it was built, these conditions are now greatly changed. Several years ago the firm of Wm. Sellers & Co., Incorporated, acquired the patent rights for the commercial manufacture of this machine, and have devoted themselves to gradually decreasing the cost and increasing the speed of operation, while scrupulously retaining the original marvelous delicacy and accuracy. Improved arrangements for rapidly clamping test pieces—preserving true alignment—so that they cannot possibly be subjected to torsional or bending strains, when a straight pull is desired, and other new mechanical devices have successfully overcome the former objections and introduced novel advantages. An idea of the possible speed of tests when the Emery machine is properly adapted to special work may be gleaned from the daily records of the Washburn & Moen Co., of Worcester, Mass., where an ordinary day's work upon their machine is 600 records of ultimate stress and elongation of wire samples, and, on busy days more than 700 separate tests have been recorded.

Until recently there appears to have been no uniform standard of tests for leather used in the manufacture of shoes and other articles required for use in the United States Government service. Each manufacturer of leather, in order to show to the purchaser the quality of his product, used various crude methods of his own, one of which was to puncture a piece, and then force his finger or some implement through the opening and tear it apart. Others would press their thumbs through the leather and note the resistance to tear—certainly "a rule-of-thumb" method. The employment of such tests as these proved, of course, entirely unsatisfactory to the officers in charge of purchasing, and led eventually to the design of a special testing-machine and the adoption of a standard, whereby uniform and comparative tests could be obtained, and all leather placed upon its relative merit. Testing machines have been applied to all kinds of material, but this is a new field and one that is destined to excite considerable interest. Every manufacturer wants to excel in the quality of his product, and when he has once attained a high grade of material he is particularly anxious to get full value for it. There is nothing so disastrous to a manufacturer as to be without a standard by which good material can be appreciated and paid for, and poor material condemned and rejected. It is of just as much importance to the manufacturer of leather to determine the quality of his output by actual tests as it is for a dealer in fluids to measure the same by the quart or gallon, or manufacturers of fabrics to measure by the yard.

The American Machinist, in its issue of February 13th, has the following to say of us, which, being the only unfavorable criticism we have seen, we reprint: "THE DIGEST OF PHYSICAL TESTS AND LABORATORY PRACTICE is the name of a new quarterly published by Frederick A. Riehlé, of Philadelphia, and is an unusually ambitious and interesting example of that class of journals that have been denominated 'House Organs,' and which are the outgrowth of a manufacturer's idea that not enough is said in the regular technical journals respecting his special line of work, and that by starting a technical journal of his own he can secure adequate treatment of the subjects he is specially interested in, and can at the same time do his own advertising more cheaply than it can be done otherwise. The scheme often looks promising, but in practice it seldom, if ever, works well. It costs nothing whatever to get really interesting matter into the best of technical journals, and matter that is not sufficiently interesting to get into them will find few readers. Though there are sound economic reasons why very few manufacturers can long continue such a publication, that does not alter the fact that the relatively few engineers who are more interested in physical tests of materials than in any other branch of work will find much to interest them in this first number of the new journal referred to, which is admirable in many respects, contains good articles on the subjects indicated, and is well gotten up mechanically, good illustrations, well printed on good paper. It is in magazine form, 6x9 inches standard, and the first number contains 86 pages." We think *The American Machinist*, as shown by its attitude at the first appearance of *Machinery*, is inclined to be the opposite of gallant in its criticisms of its contemporaries, but, like *Machinery*, we would say that "there is room for us both, neighbor." Of course, all our readers know, or at least we wish them to know, that our Publisher, Mr. Frederick A. Riehlé, is the manufacturer of the well-known Riehlé Testing Machine, to which business he has ardently devoted himself for the past thirty years, and we consider that the DIGEST is only a natural outgrowth of this train of thought. It was with no little misgiving that a venture of this kind was undertaken, but it was not done without due deliberation, and the favorable comments that the first number elicited from the many are flattering in the extreme, and far outweigh the criticisms of the few whose line of work can hardly make them competent judges of this, the newest of the sciences.

The Publisher of THE DIGEST OF PHYSICAL TESTS considers an acknowledgment due the many kind friends and substantial supporters of that magazine, and wishes to express his thanks for the large number of congratulatory letters and assurances of valuable contributions which have been received from all parts of the country. In subsequent numbers the DIGEST will contain, from time to time, valuable translations from the German and French, as it is acknowledged that the subject of testing has received far more attention abroad than in the United States. We are assured that these translations are awaited with interest.

The attendance at the annual meeting of American Institute of Mining Engineers, recently held at Pittsburg, was exceptionally large. The opening session was held on Tuesday, February 18th, which was principally taken up by speeches of welcome and the President's address. Wednesday was given over to an excursion to Homestead, where the large beam mill, the armor-plate plant, plate mill, armor-plate mill, and open-hearth plants were visited in turn, followed by a highly interesting tour through the Westinghouse Electric and Manufacturing Company's new plant at East Pittsburg, and the Edgar Thomson steel plant at Bessemer. Thursday morning and afternoon was devoted to the continuance of the discussions on the physics of cast iron, many interesting and valuable facts being brought to light. Among the contributions to the debate were C. R. Baird & Co., E. K. Landis, A. E. Outerbridge, Jr., W. R. Webster, and T. D. West. Papers were also read by H. L. Hollis, on the "Walrand-Legenisel Process;" by H. A. J. Wilkens, on the "Magnetic Separation of Non-Magnetic Material;" by R. H. Richards, on "Experiments in Sorting before Sizing;" by Thomas Robins, Jr., on "Conveying Belts and Their Uses," and by Guy R. Johnson, on "The Embreeville Estate of Tennessee." In the evening a banquet was held at the Monongahela House, in which most of the members and their guests participated. Speeches were made by Joseph D. Weeks, the retiring president, and by E. G. Spilsbury, the newly elected president. Secretary R. W. Raymond responded to the toast, "Claims;" R. H. Hunt, "Defects;" Dr. D. T. Day, "Figures;" D. Riddle, "Mines and Minds," and A. P. Burgwin, "The Law," which was, by far, the wittiest and most enjoyed speech of the evening. On Friday, the last day of the convention, the members visited the McKee Brothers' Glass Works, Jeannette; The Latrobe Steel Works, Latrobe; and the Penn Salt Co., Natrona, Pa.

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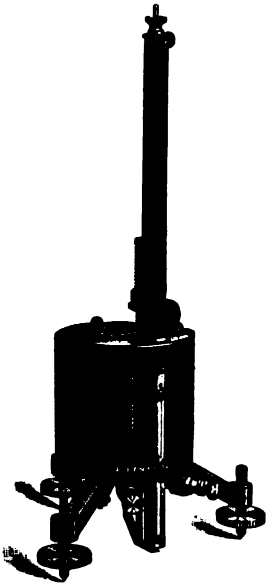

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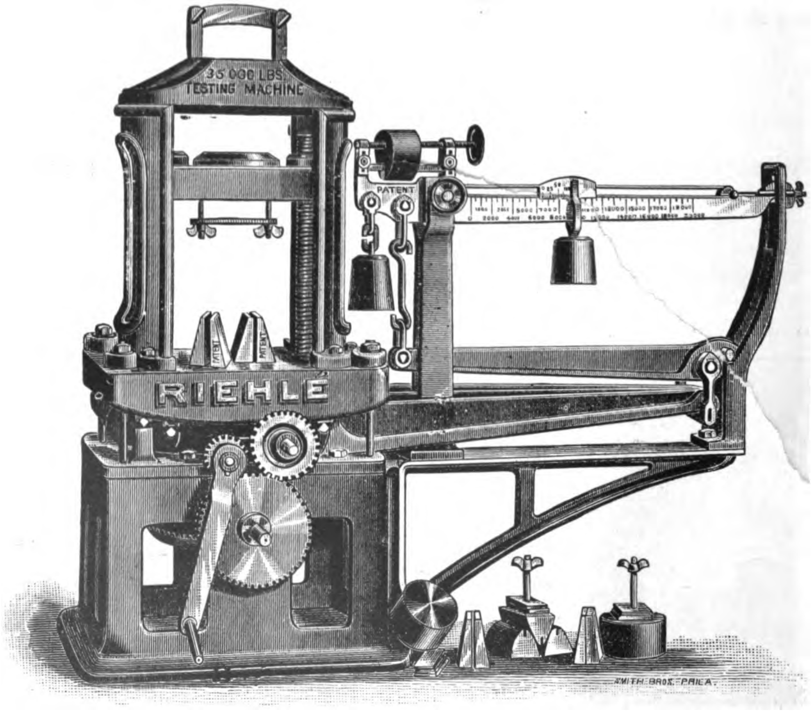

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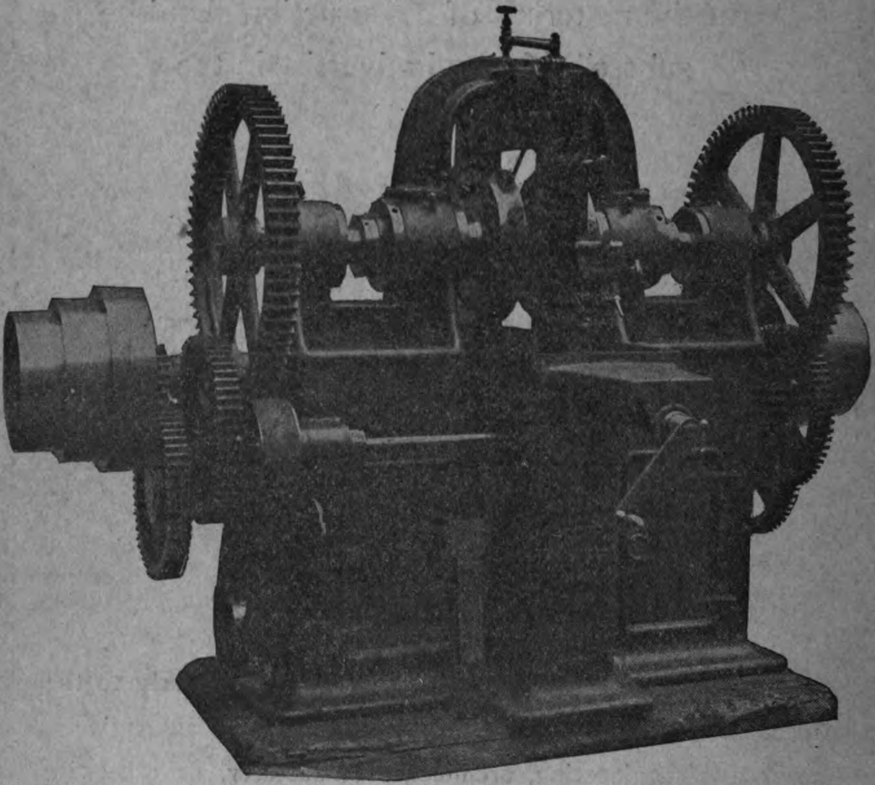

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Vol. I. JULY, 1896. No. 3.

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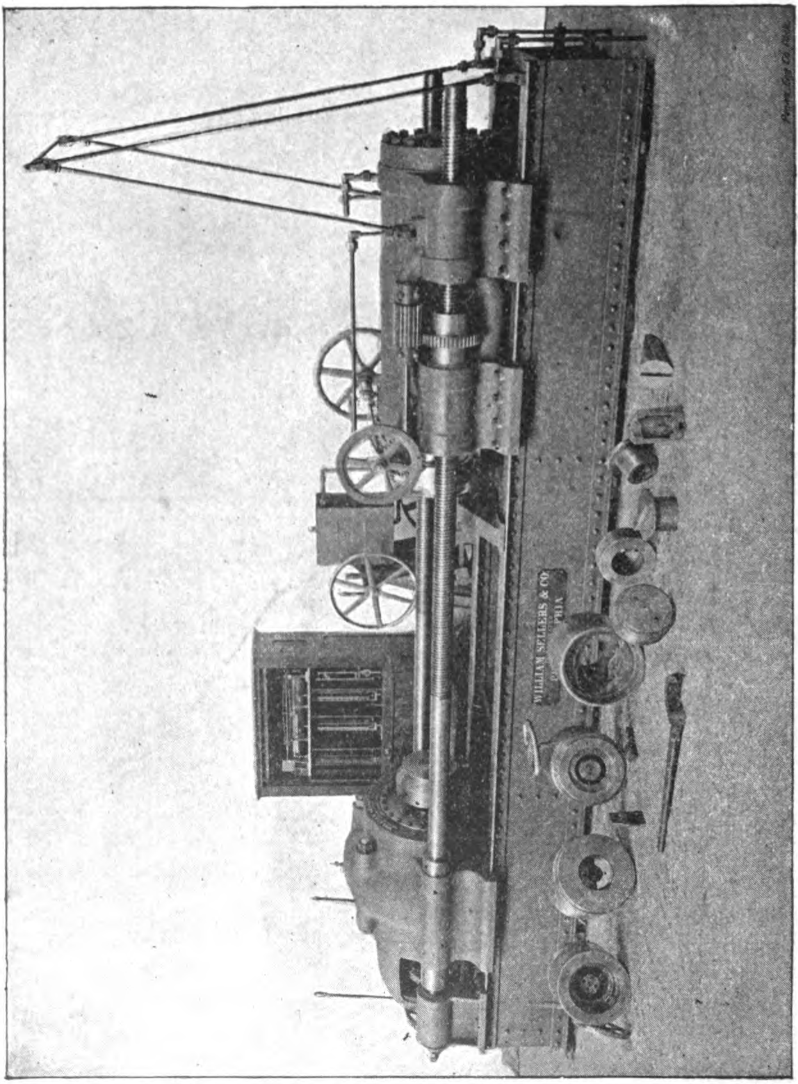

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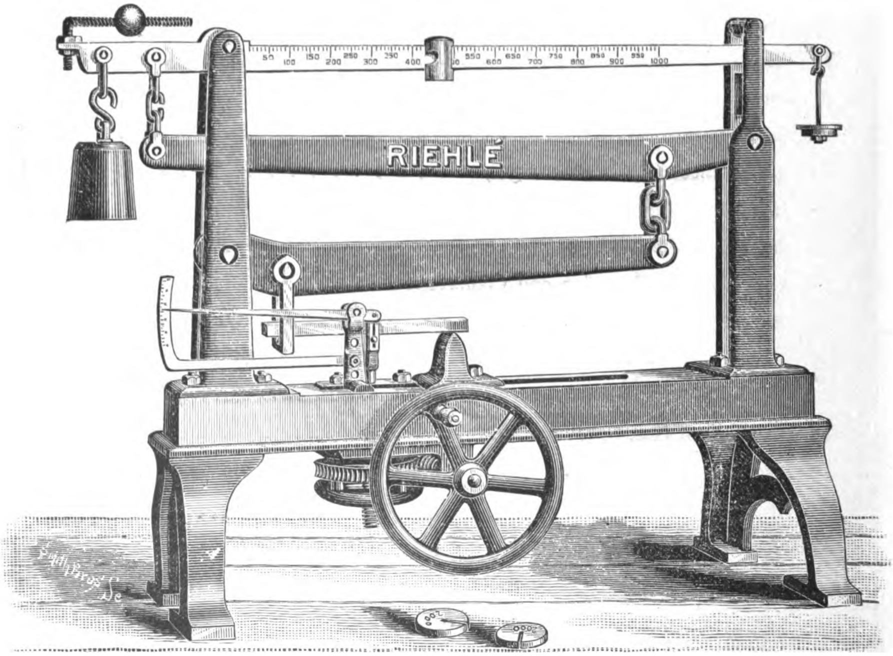

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Mit bestem Gruß.

J Bauschinger

LATE DIRECTOR OF THE TESTING LABORATORY OF THE SCHOOL OF TECHNOLOGY OF MUNICH.

Digest of Physical Tests.

A RÉSUMÉ OF PRACTICAL TESTS MADE IN THE
LABORATORIES OF THE WORLD.

Vol. I. JULY, 1896. No. 3.

PROFESSOR JOHANN BAUSCHINGER.

A Biographical Sketch Compiled by Prof. J. B. Johnson, from a more extended Memoir by Prof. A. Martens.

PROFESSOR BAUSCHINGER was born in Nürnburg in 1834. His father was an artisan, and had a large family. Young Bauschinger, therefore, at an early age, saw the earnest side of life, and he learned to have faith in his ability to support himself. At the age of fourteen he began giving private lessons. However, gifted with a strong will power, he completed the Polytechnic School with honors in 1853, at the same time receiving his certificate from the Latin school. Having selected mathematics and physics as the branches which he desired eventually to teach, he studied for three years at the University of Munich. Under von Lamont he studied with great enthusiasm theoretical and practical astronomy. He had the rare opportunity of using the astronomical and magnetic instruments in the royal observatory at Bogenhausen. Here he developed that faculty of keen observation and learned the scientific methods of discussing and reducing observations to obtain the most probable results, which afterward stood him in such good stead.

In the fall of 1856, after having passed the examinations for teacher in mathematics and physics, he accepted the position as assistant in physics and descriptive geometry at the Polytechnic School in Augsburg, and in 1857 he was called to Fürth, where he became teacher of mathematics and physics at the Royal Industrial School.

In 1866 Bauschinger was transferred to the Academy in Munich, and two years later he became professor there of mechanical engineering at the newly-founded Technical School. In 1870 he became director of the testing laboratory, which was built under his direction and according to his plans. Here he remained and labored in the interest of science until his death.

At Fürth Bauschinger had already developed a literary activity. Papers by him on subjects pertaining to mechanical engineering and thermodynamics appeared in various publications. As an independent work he published his popularly-written *School of Mechanics*. This was followed in 1871 by *The Elements of Graphical Statics*.

Without doubt Bauschinger's best and most valuable publications were those relative to his physical tests. His *Indicator Trials on Locomotives* had been begun as early as 1865, and they were continued at Munich under extreme difficulties on account of the great amount of work he was called on to perform as professor in the Technical School. However, Bauschinger's main field of investigation was in the testing of materials. Here he earned great and indisputable fame.

His writings since 1871, published in the *Journal of the Society of Bavarian Architects and Engineers*, and other publications, and later in his *Communications from the Testing Laboratory of the School of Technology of Munich*, will long furnish ample data for the study of the strength of materials. His was the first public testing laboratory in all Germany, and it has continued to stand as the most noted in the world in many respects. This institution, with its furnishings, has served as a model for all later similar establishments.

Bauschinger greatly improved our means for testing materials by the invention of accurate measuring apparatus, one example of which was his application of the Gauss method of mirror readings by which all measurements are very accurately obtained. Many other accurate measuring and testing devices, now commonly employed, are due to him.

Referring now to his contributions to the science of the strength of materials, in his "Communications" we may say, in short, that in the numbers 1, 4, 5, 7, 8, 10, 11, 18, and 19 he treats of the strength of cements, mortars, and artificial and natural building stones. In numbers 1, 7, and 8, Bauschinger speaks of his numerous tests of cements, and cement and lime mortars. In these as well as in the tests of artificial and natural stones discussed in numbers 4, 5, 10, and 11, 18, and 19, different methods were used, and the various results were compared. He has made a special study of the elasticity and strength of building stones. At the same time and in the most detailed manner, he made cross-bending, tension, compression, and shearing tests of the same materials.

For the investigation of the wearing of stones a singular method was devised. The effects of freezing are minutely examined and compared, and many simplifications are given to the conscientious worker.

In No. 6 of the "Communications" are treated the laws of compression. Besides discussing the older works of the French and English his own experiments are given. In other numbers, 2, 3, 13, 20, and 21, the properties of metals, the law of the resisting power of iron and stone pillar in fire (numbers 12 and 15), and the properties of wood (numbers 9 and 16), etc , are discussed. The change of the elastic limit and strength of iron and steel, due to stretching and crushing, is especially to be noticed (number 13).

The "Meetings for the Agreement as to the Methods of Testing Building and Construction Material," of which he was president, were entirely due to his energetic action. The reports of these meetings are contained in numbers 14 and 22 of his "Communications," the latter of which he did not live to complete. These "meetings" led directly to the permanent International Association which has since been organized.

His work was recognized in all parts of the world. He was made member of the Royal Prussian Academy of Architects, also of the Royal-Bavarian Academy of Science in Munich, and of the Imperial Academy of Naturalists at Halle, also honorable member of the American Society of Mechanical Engineers, of the Royal Imperial Technological Industrial Museum in Vienna, and of the Royal Bavarian Industrial Museum in Nürnburg, etc., etc.

He died on the 25th of November, 1893, after having given the scientific world the results of his experiments, his theories, and his improvements in testing machinery, which will ever stand as an indestructible monument to his memory.

BRITTLE MATERIALS UNDER COMPRESSIVE STRESS.

By J. B. Johnson, Professor Civil Engineering, Washington University, St. Louis.

ENGINEERING materials may be divided into two general classes, according to their manner of failure in compression.

Plastic or viscous materials are those which will flow without showing any other indication of failure under a sufficient compressive load.

Brittle or comminuible materials are those which will crush to a powder, crumble to pieces, or fail by shearing on definite angles under a compressive load.

In the former case are such materials as wrought iron, soft and medium steel, the alloys, lead, copper, zinc, and the like. Of the latter class are cast iron, hard or tempered steel, brick, stone, cement, etc. The laws of failure of these two classes are very different, and they will, therefore, have to be discussed separately.

There is no such thing as an "ultimate strength" in compression of a plastic body. There is, however, a definite elastic limit, the same as in tension. Beyond this limit the material simply spreads, and increases the area of its cross-section indefinitely under an increasing load. The elastic limit in compression of such a material is the greatest load from which the specimen will fully recover, or it is the greatest load within which the stress and strain bear a constant ratio to each other. This elastic limit in compression for wrought iron and steel is fortunately about the same in pounds per square inch as the elastic limit in tension. It is not customary, therefore, to test such materials in compression, but to assume that they have the same elastic limit in compression which they are found to have in tension.

THE ANGLE OF RUPTURE.

Experiments show that all such materials when subjected to a compressive load fail by shearing on certain definite angles. The resistance to movement along these angles is made up of two parts. First, the strength of the material to resist shearing, and second, the frictional resistance to motion along this plane. The sum of these two resistances must equal the shearing component of the load imposed,

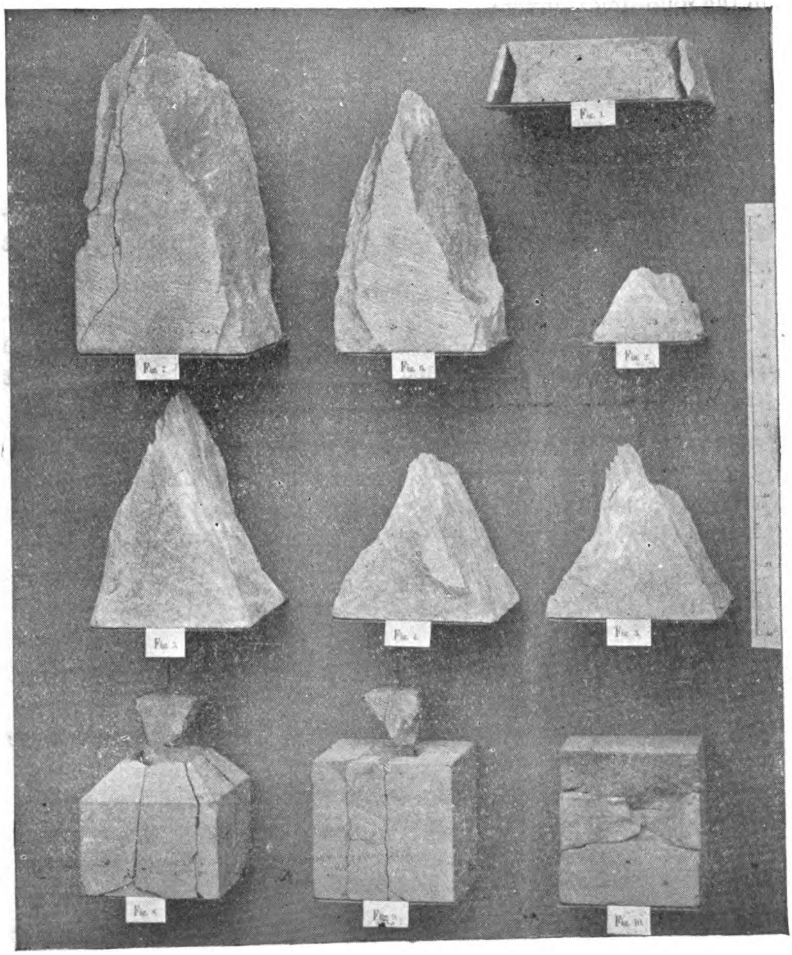

PLATE I.

when resolved along the shearing plane. To find what this angle should be, we may equate the two resistances here described, with the shearing force, and find the angle of rupture, the determining condition being that this angle shall be that which offers the least total resistance to failure under a crushing load. This angle may be found in the following manner:

Let s = shearing strength of the material per square inch.
A = area of prism = 1 square inch.
θ = angle of rupture.
p = crushing load per square inch.

The tendency to slide on the plane of rupture is $p \sin. \theta$.

The resistance to sliding is $s \sec. \theta + fp \cos. \theta$, where f is the coefficient of friction = $\tan. \phi$, where ϕ = angle of repose. Hence at failure

$$p \sin. \theta = s \sec. \theta + fp \cos. \theta \qquad (1)$$

It is evident that the angle of rupture will be such as to cause failure under the least load, hence if θ be taken as the independent variable we will have, at rupture,

$$\frac{d\,p}{d\,\theta} = - s\,(\cos.^2 \theta - \sin.^2 \theta + 2 f \sin. \theta \cos. \theta) = O.$$

or

$$f = -\tfrac{1}{2}\left(\frac{\cos.^2 \theta - \sin.^2 \theta}{\sin. \theta \cos. \theta}\right) = -\frac{1 - \cot.^2 \theta}{2 \cot. \theta} = - \cot. 2\,\theta, \qquad (2)$$

whence, since $f = \tan. \phi$, we have

$$\tan. \phi = - \cot. 2\,\theta = - \tan. (90^\circ - 2\,\theta) = \tan. (2\,\theta - 90^\circ)$$

or

$$\phi = 2\,\theta - 90^\circ \text{ and } \theta = \frac{90^\circ + \phi}{2} = 45^\circ + \frac{\phi}{2}. \qquad (3)$$

That is to say, *the angle of rupture is 45° plus one-half the angle of repose.*

If the friction had been omitted, we would have had—

$$p \sin. \theta = s \sec. \theta, \text{ whence } \frac{d\,p}{d\,\theta} = s\,(\cos.^2 \theta - \sin.^2 \theta) = \theta$$

$$1 - 2 \sin.^2 \theta = \theta;\ 2 \sin.^2 \theta = 1, \text{ or } \theta = 45^\circ \qquad (4)$$

It has been customary to neglect the friction, and to state that the planes of rupture make this angle of 45° with the horizontal,* but the actual plane of rupture, when the specimen has sufficient height, is about 55° with the horizontal, or 35° from the direction of the ap-

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* *Coulomb* is responsible for this theory, while *Navier* has given the true analysis. Most writers, including Rankine, have followed Coulomb, however.

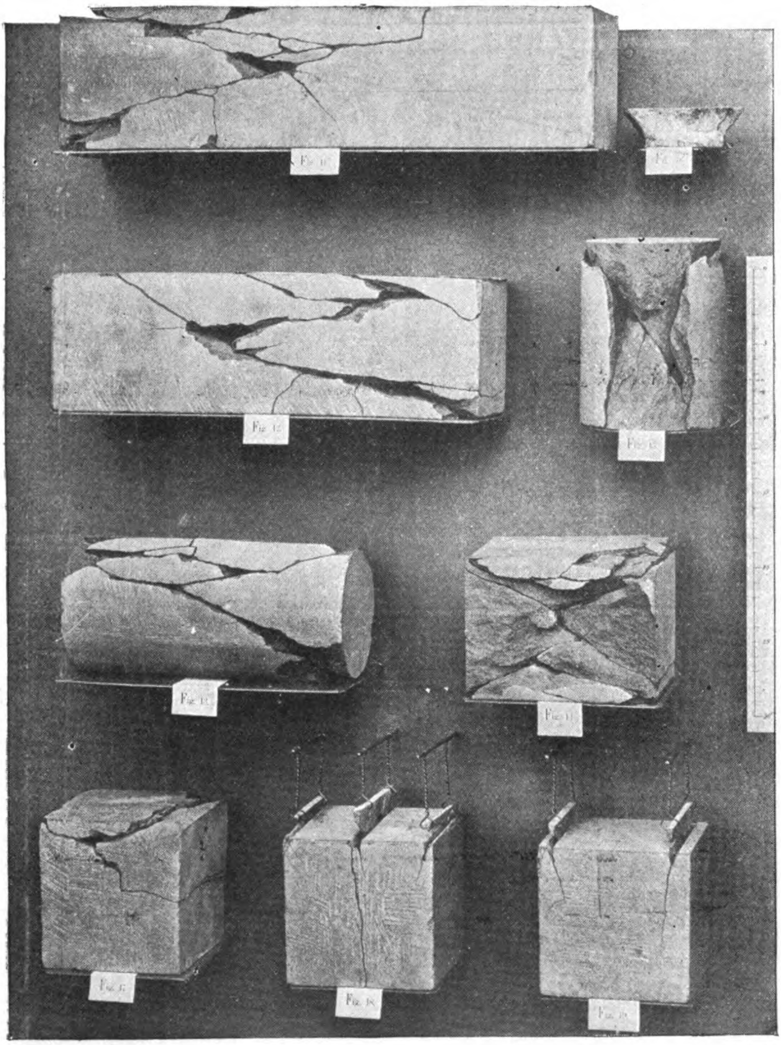

Plate II.

plied load. See Plates I and II, showing tests on sandstone made by Professor Bauschinger. Mr. Charles Bouton has shown* that the theoretical angle of rupture is borne out in practice with many kinds of materials. See Plate III for photographic views of crushed specimens of cast-iron cylinders of various heights, showing angle of rupture.

The following table gives the results of Mr. Bouton's determinations of the theoretical and the actual values of this angle:

MATERIAL.	NO. OF EXPERIMENTS.	OBSERVED ANGLE OF RUPTURE.	OBSERVED ANGLE OF REPOSE.	THEORETICAL ANGLE OF RUPTURE.	DIFFERENCES.
"F." Cast Iron, . . .	24	54.8° ± 0.2°	20.6°	55.3°	— 0.5°
"C. W." Cast Iron, . .	24	55.0° ± 0.2	16.9°	53.4°	+ 1.6°
Limestone, ...	4	62.2°	33.4°	61.7°	+ 0.5°
Asphalt Paving Mixture,	3	59.7°	27.3°	58.6°	+ 1.1°
Milwaukee Brick, . . .	4	58.2°	27.0°	58.5°	— 0.3°

The "F." cast iron was good foundry iron, having a tensile strength of 22,000 pounds per square inch, and a modulus of elasticity of 14,500,000. The "C. W." iron was car-wheel iron, having a tensile strength of 20,000 pounds per square inch, and a modulus of elasticity of 6,500,000, or less than one-half of the former.

RELATION BETWEEN CRUSHING STRENGTH AND SHEARING STRENGTH.

To show the relation of the crushing strength to the shearing strength, we have from Equation (1) above,

$$s = p\,(\sin.\ \theta \cos.\ \theta - f\,p \cos.^2 \theta)\,;$$

also from Equation (2)

$$f = -\cot.\ 2\,\theta = -\frac{\cos.\ 2\,\theta}{\sin.\ 2\,\theta} = -\frac{\cos.^2 \theta - \sin.^2 \theta}{2 \sin.\ \theta \cos.\ \theta}.$$

Substituting this value of f we find—

$$s = \frac{p \cos.\ \theta}{2 \sin.\ \theta} = \frac{1}{2}\,p \cot.\ \theta, \qquad (5)$$

or

$$p = 2\,s \tan.\ \theta. \qquad (6)$$

where p = compressive strength in pounds per square inch,
and s = shearing strength in pounds per square inch.

---

* In a thesis for the degree M. S. at Washington University, 1891, entitled *Theory and Experiments on the Laws of the Crushing Strength of Short Prisms.*

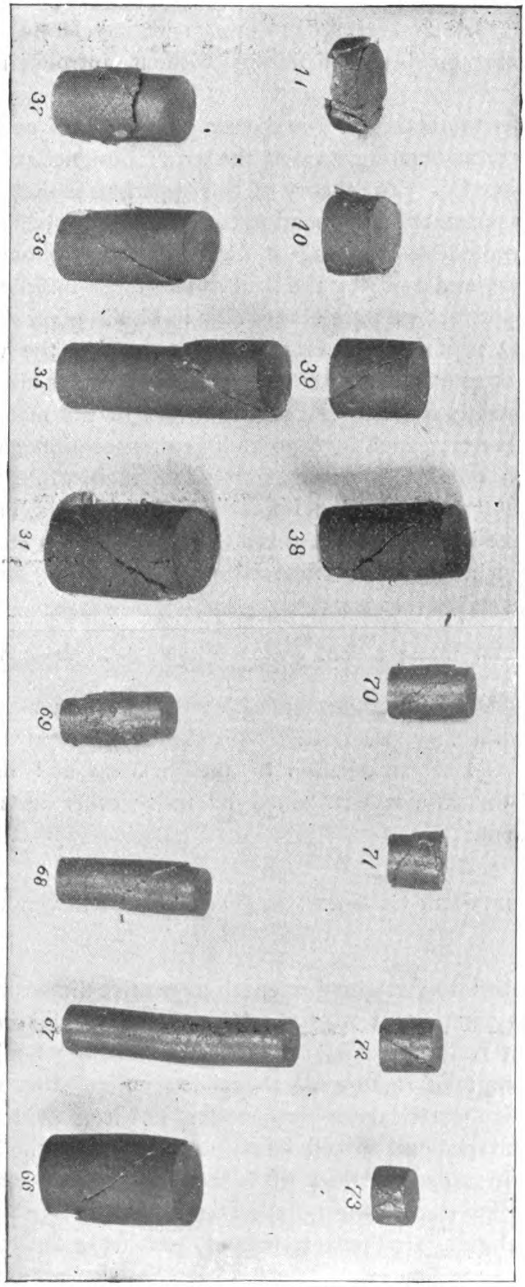

Plate III.

This relation was also shown by Mr. Bouton to be well borne out in practice. The great trouble to prove such a relation is to find s experimentally on brittle materials without introducing bending stresses.

In order to obtain the true shearing strength of cast iron uninfluenced by cross-bending stresses, the writer designed the apparatus shown in Plate IV. The theory of this apparatus is that if the specimen can be prevented from bending there will be no bending stresses. It is so prevented by clamping it firmly at the two ends, and also in the middle, and applying the load to the upper middle clamp-bar. With this apparatus we were always able to obtain good shearing fractures without rupture from cross-breaking, so that the value of the shearing stresses obtained by the use of this apparatus are regarded as being very nearly the true shearing strength of the material. Thus a cast-iron bar 0.77 inch by 0.90 inch in cross-section gave a shearing strength of 28,000 pounds per square inch, while the average crushing strength of a cylinder having an equal area, and a height equal to twice its diameter, cut from the same bar, was 82,960 pounds per square inch. As the average value of the shearing angle for this material was 55°, we have:

Crushing strength$=2$ s tan. $\theta=2\times 28{,}000\times 1.43=80{,}000$ pounds.

This shows an agreement with the actual average crushing strength within four per cent. This close agreement between the theoretical and actual relation of the shearing and the crushing strength of cast iron was sustained by many other tests showing a like agreement.

RELATION BETWEEN CRUSHING STRENGTH AND RELATIVE DIMENSION OF SPECIMEN.

The relation of crushing strength to relative dimensions of specimen is a very important matter. Hitherto nearly all crushing test specimens of brittle materials have a cubical form. So long as the theoretical angle of rupture was thought to be 45° this was proper, but since this theoretical angle approaches 60° it is evident that the height of the specimen should be at least 1½ times the least lateral dimension, in order to allow of failure on a normal angle. Prof. Bauschinger has studied this question very exhaustively and the following conclusions are drawn from studies of his results of tests on a

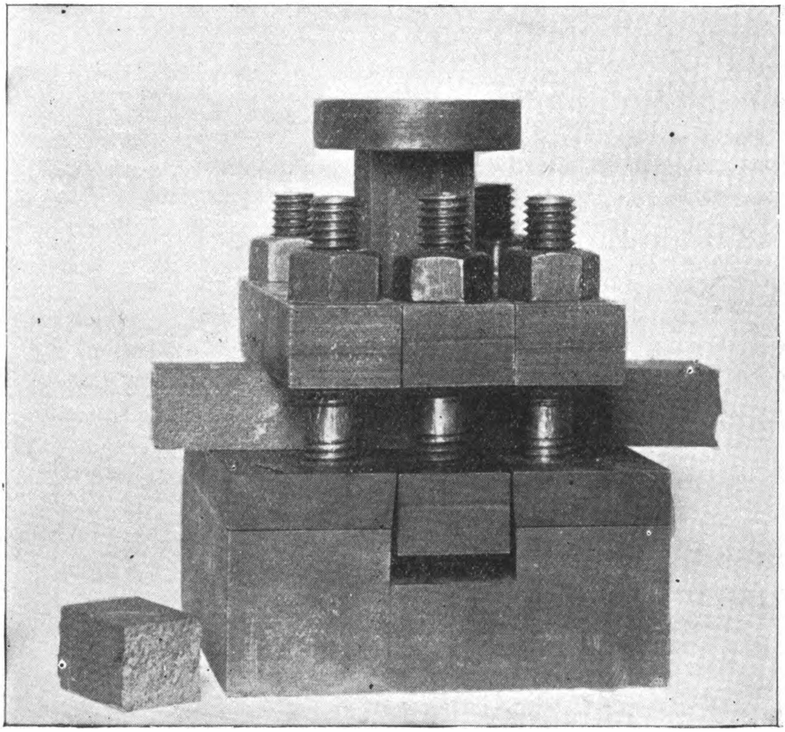

Plate IV.

very uniform quality of fine Swiss sandstone, all possible refinements as to appliances having been introduced.*

Prof. Bauschinger recommends the formula

$$p = \sqrt[4]{\frac{\sqrt{A}}{u}}\left(a + b\frac{\sqrt{A}}{h}\right) \qquad (7)$$

for all shapes of cross section and for all relative heights, where

p=crushing strength per unit of area,
A=area of cross-section,
u=perimeter of cross-section,
h=height of specimen,
a and b=constants.

For rectangular cross-sections the following formula serves very well:

$$p = k + k' \frac{\sqrt{A}}{h} \qquad (8)$$

where k and k′ are constants.

The application of this formula is shown in Plate V, in which the tests were on three sets of sandstone prisms, of the dimensions 2½ inches by 5 inches; 3¾ inches by 5 inches, and 5 inches by 5 inches in cross-section respectively, the heights of each set varying from 1½ to five times the least lateral dimension. It is seen that formula (8) fits the results very well, the equation of the full line being

$$p = 5{,}600 + 1{,}400 \frac{\sqrt{A}}{h} \qquad (9)$$

in pounds per square inch.

If a simpler formula is desired, the following may be chosen:

$$p = \text{K} + \text{K}' \frac{b_1}{h} \qquad (10)$$

where b_1 = least lateral dimension.

Plate VI shows how well this law fits the observations, the equation for this locus being, for the tests on sandstone,

$$5{,}500 + 1{,}565 \frac{b_1}{h} \qquad (11)$$

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* Mittheilungen aus dem Mechanisch-Technischen Laboratorium der K. Technischen Hochschule in München. von J. Bauschinger, Vol. VI, 1876.

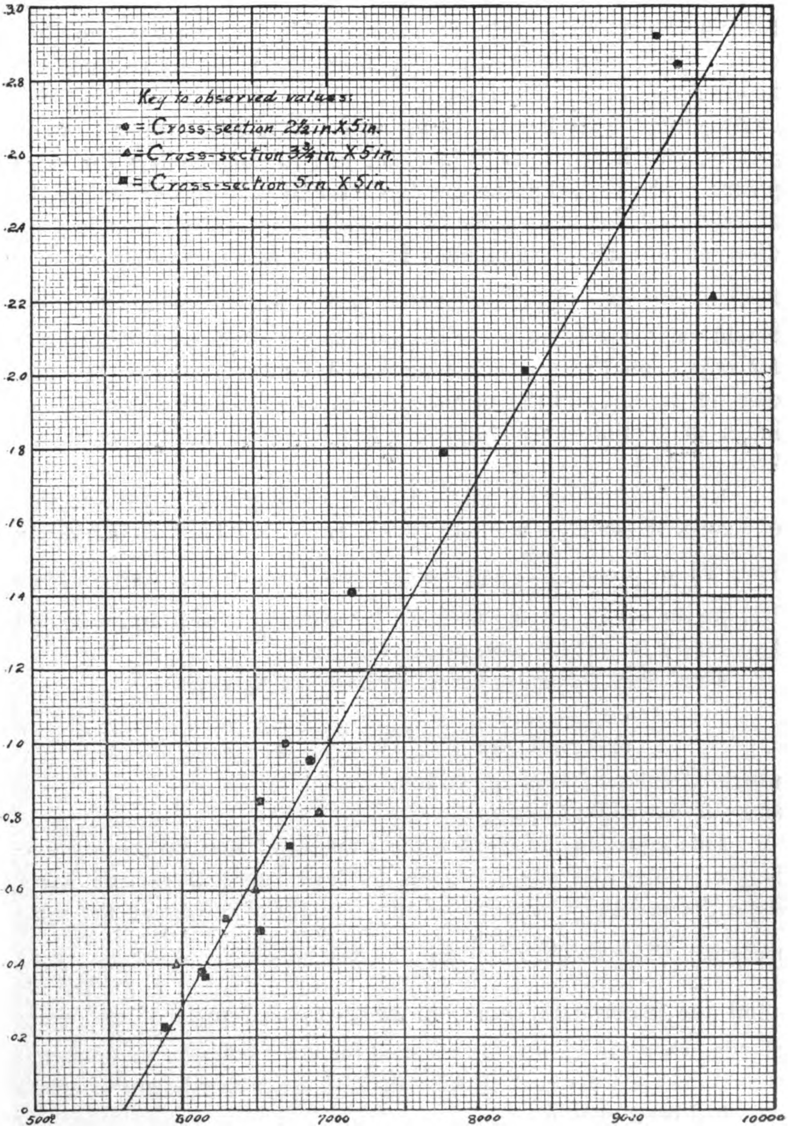
Key to observed values:
● = Cross-section 2½ in X 5 in.
▲ = Cross-section 3¾ in. X 5 in.
■ = Cross-section 5 in X 5 in.
3.0
.28
.26
.24
.22
.20
.18
.16
.14
.12
.10
0.8
0.6
0.4
0.2
0
5000
6000
7000
8000
9000
10000

PLATE V.

The larger curve on this plate represents the law for sandstone prisms, and the smaller one the law for cast-iron cylinders. The experiments for the former were made by Prof. Bauschinger, and for the latter by Mr. Bouton. Mr. Bouton made his tests on five bars each, of two kinds of cast iron, turning from these ten bars nearly one hundred cylinders. The tests on the longer cylinders have been excluded from the results plotted, as their length caused them to bend greatly, and hence their failure did not follow the law for short prisms. The plotted points on the tests of cast iron represent the average results of the number of similarly proportioned cylinders indicated in the affixed numerals. In these tests there seems to be a possible minimum point at about $\frac{h}{d} = 1.5$, this being about the height which equals tan. θ, or the least height offering an opportunity for failure on the theoretical angle. Why this should be the case does not appear, and the mean curve has been drawn without showing such a minimum indication. (No equation for this curve has been sought.)

In order to show the relation of the strength of a prism to that of a cube, Bauschinger's observations have been used, as plotted in Plate VI to p and $\frac{h}{b}$*, and the curve and results as shown on Plate VII are the result. A few tests on limestone prisms from the Berlin Laboratory Report for 1884 are also plotted.

Thus, from this mean curve, we have the equation:

$$\frac{\text{Strength of Prism}}{\text{Strength of Cube}} = 0.778 + 0.222\,\frac{b_1}{h} \qquad (12)$$

where b_1 = least lateral dimension,
and h = height of prism.

This equation shows that the strength of a stone prism whose height is one and one-half times its least lateral dimension has a strength equal to 92 per cent. of the strength of a cube of the same material. This height of $\frac{h}{b_1} = 3/2$ was found to be necessary to allow the material to shear on the theoretical angle of $45° + \frac{\phi}{2}$. Hence, when the cubical form is used for test specimens in crushing, the results are 9 per cent. greater than if the proper height of specimen had been chosen.

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* This law holds between the limits $h = 0.4b$ and $h = 5b$, these being the limits of the observations.

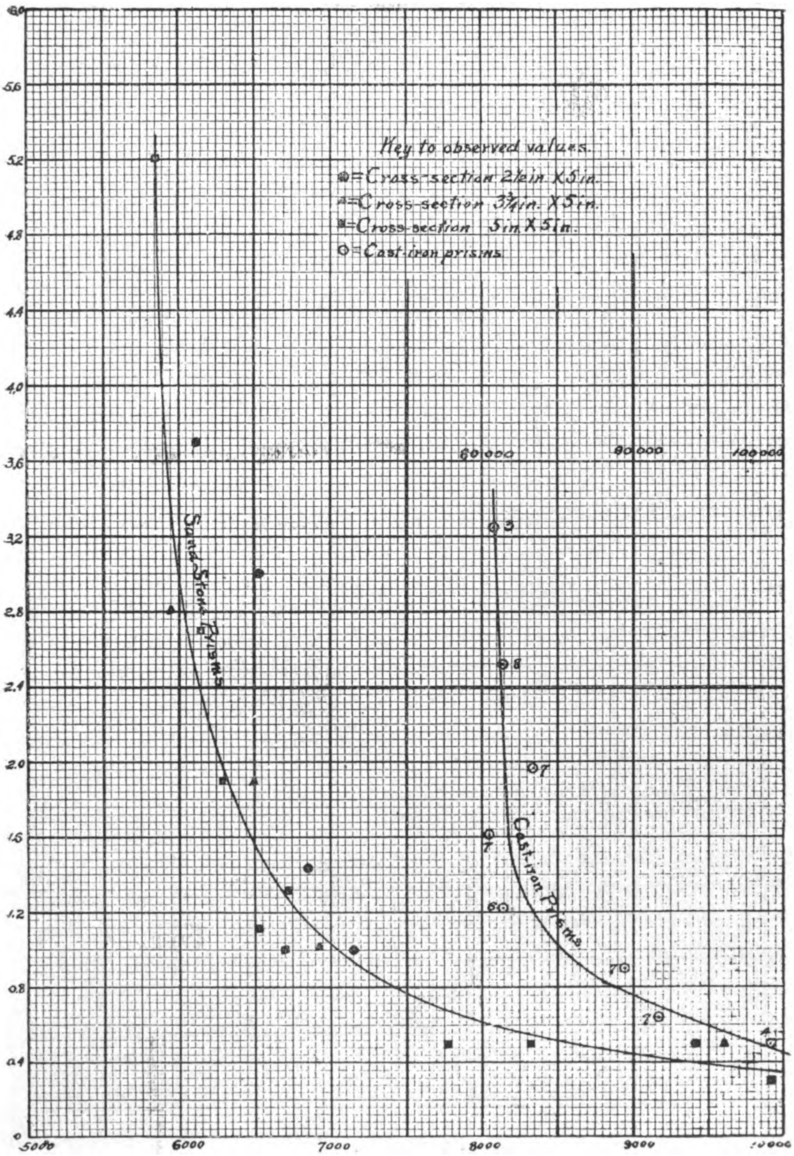

Key to observed values.
● = Cross-section 2½ in. X 5 in.
▲ = Cross-section 3¾ in. X 5 in.
■ = Cross-section 5 in. X 5 in.
⊙ = Cast-iron prisms
Sand Stone Prisms
Cast-iron Prisms
6.0
5.6
5.2
4.8
4.4
4.0
3.6
3.2
2.8
2.4
2.0
1.6
1.2
0.8
0.4
0
5000
6000
7000
8000
9000
10000
60000
80000
100000
3
8
7
7
6
7
7
4

Plate VI.

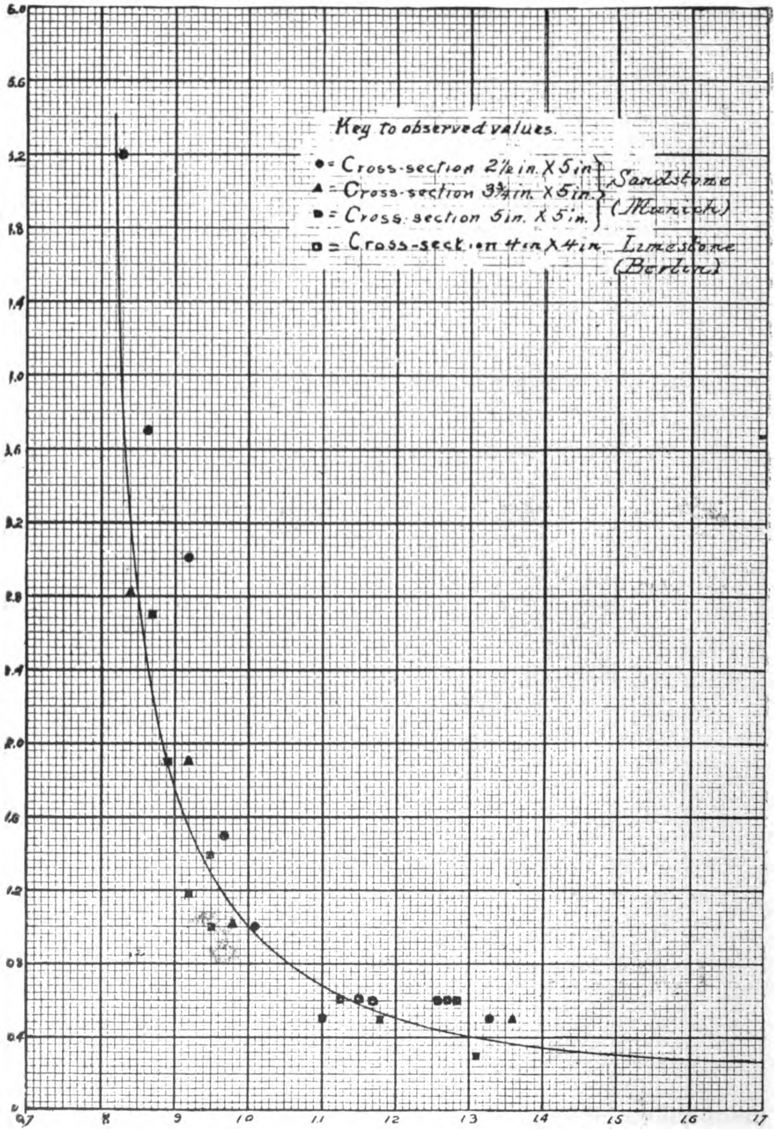

Key to observed values.
● = Cross-section 2½ in. X 5 in.
▲ = Cross-section 3¾ in. X 5 in.
■ = Cross-section 5 in. X 5 in.
□ = Cross-section 4 in. X 4 in.
Sandstone (Munich)
Limestone (Berlin)
6.0
5.6
5.2
4.8
4.4
4.0
3.6
3.2
2.8
2.4
2.0
1.6
1.2
0.8
0.4
0
0.7
.8
.9
1.0
1.1
1.2
1.3
1.4
1.5
1.6
1.7

PLATE VII.

Also, if a brick, for instance, be tested flatwise, in which position, $\frac{h}{b_1} = 0.5$, we find from this curve it will give a result 22 per cent. greater than that for a cube, and 33 per cent. greater than that for a specimen in which $\frac{b_1}{h} = \frac{2}{3}$. In other words, the results from tests on cubes are 9 per cent. too large, and on bricks flatwise they are 33 per cent. too large.

It will also be noted that, so far as these tests go, *the unit strength of the material is no function of the size of the specimen, but only a function of its form.*

EFFECT OF CHAMPFERED EDGES.

If the edges of a cube or prism be champfered off as shown in Plate VIII, and the load applied uniformly over the reduced area, the law of the variation of strength to relative area of compressed surface to that of the specimen, is shown by the curve on this plate.

Thus, as the area of pressed surface approaches that of the full cross-section, the load carried per unit of pressed surface decreases, as shown by the curved locus on the right, while the average load on the full cross-section increases uniformly as shown by the straight locus on the left of Plate VIII, the two loci meeting at 9,500 pounds, the strength per square inch of a full cube. These results show clearly that the bearing surface should be that of the full cross-section of the specimen, if normal results are to be obtained. The contrary has sometimes been asserted—that the strength of the specimen was not increased appreciably by the material outside the bearing surface. In other words, *crushing test specimens should be true prisms in form, without champfered edges, or rounded corners.*

Since the locus of unit strength for bearing surface, Plate VIII, comes nearly into a vertical direction as the pressed surface approaches the full area of cross-section, it follows that when the pressed surface is nearly equal to that of the full cross-section of the specimen the error introduced by considering only the pressed surface is very small. For instance, if the area of the compressed surface is 0.8 that of the full cross-section (dimensions of cross-section 0.9 those of the full section), the error introduced by considering the pressed surface only, would be by this curve, $\frac{300}{9,500} = 3.2$ per cent.

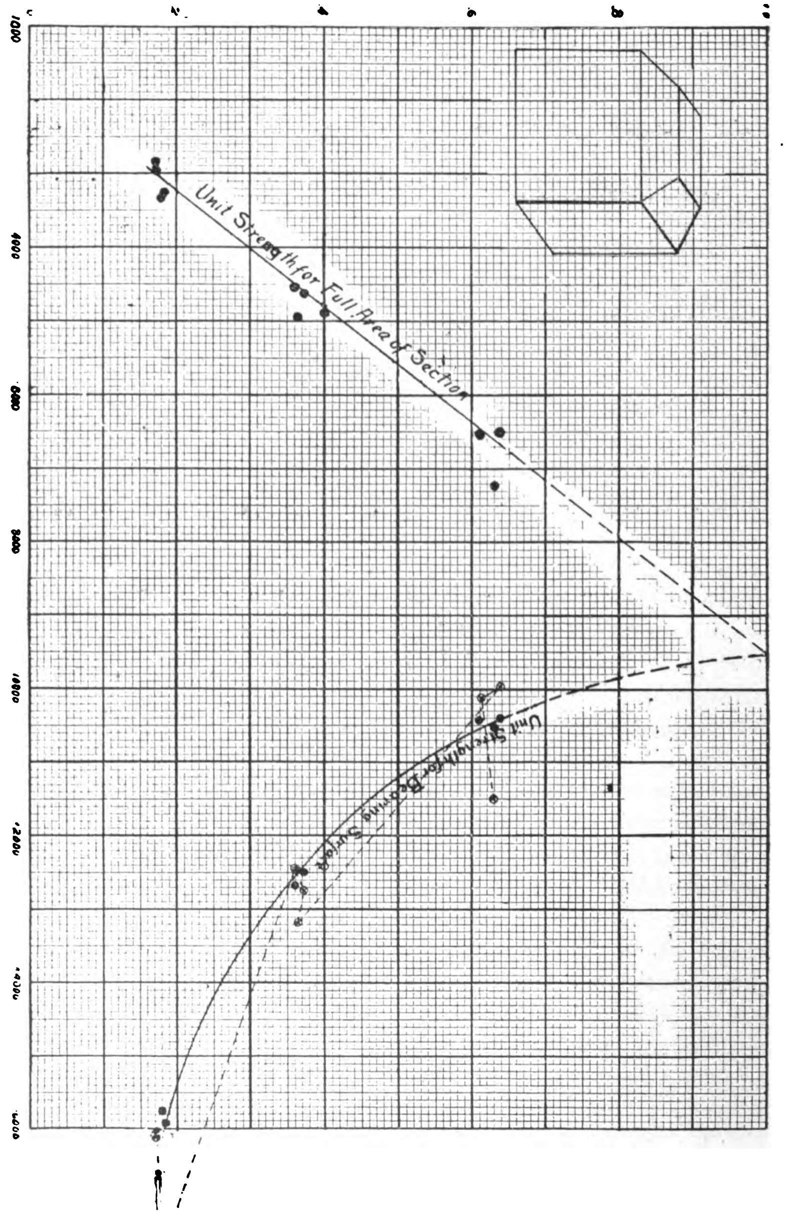

Unit Strength for Full Area of Section
Unit Strength for Bearing Surface
2
4
6
8
10
4000
6000
8000
10000
12000
14000

PLATE VIII.

EFFECT OF APPLYING THE LOAD TO A SYMMETRICAL PORTION OF ONE OR BOTH SURFACES.

When the pressed surface is square and placed symmetrically on a larger cube, the relation of the resistance per unit of pressed surface to the strength of the cube is shown on Plate IX. Here the curves are given for the small bearing on one side and also on opposite sides, and the crushing resistance computed and plotted per unit of bearing surface and also per unit of cross-section of the cube. Evidently the loci must all meet at a point where the bearing area equals the total area on each side, and this point will be the strength of a cube of this material, which was 9,500 pounds per square inch, the same as shown in Plate VIII, the material being the same.

EFFECT OF APPLYING THE LOAD TO A BELT OF ONE SURFACE.

When the bearing surface is rectangular and extends entirely across the cube, the resistance per square inch is a function of the distance of the pressed surface from the edge of the cube. This law is shown in Plate X. The material being the same as before, the strength of a cube would be 9,500 pounds per square inch. This corresponds to a distance from the edge of cube equal to 8 per cent. of the half-width. As the bearing surface had a width equal to 10 per cent. of the half-width of the specimen, it follows that the outer line of the pressed surface came within 3 per cent. of the half-width, or 1½ per cent. of the total width from the edge of the specimen when the normal strength of the material was developed.

The laws of crushing strength shown in Plates V to X apply specifically to a particular quality of sandstone. In Plate VI it is shown that cast iron follows a different law. In all probability each kind of material, or at least materials which have different angles of rupture (that is to say, different coefficients of friction), will show different curves for the several relations indicated in these plates. In the absence of any more definite information, however, on this subject, it is thought the curves shown upon these plates will serve to indicate in a general way the laws of the variation of crushing strength with the varying conditions here indicated.

By referring to Plates III and IV it will be observed that the cylinders all swelled more or less in the middle before rupture occurred. This is doubtless due to the restraining action of the friction against lateral motion on the end bearing surfaces. It is difficult to take this source of strength fully into account in a theoretical analysis of resistance to crushing.

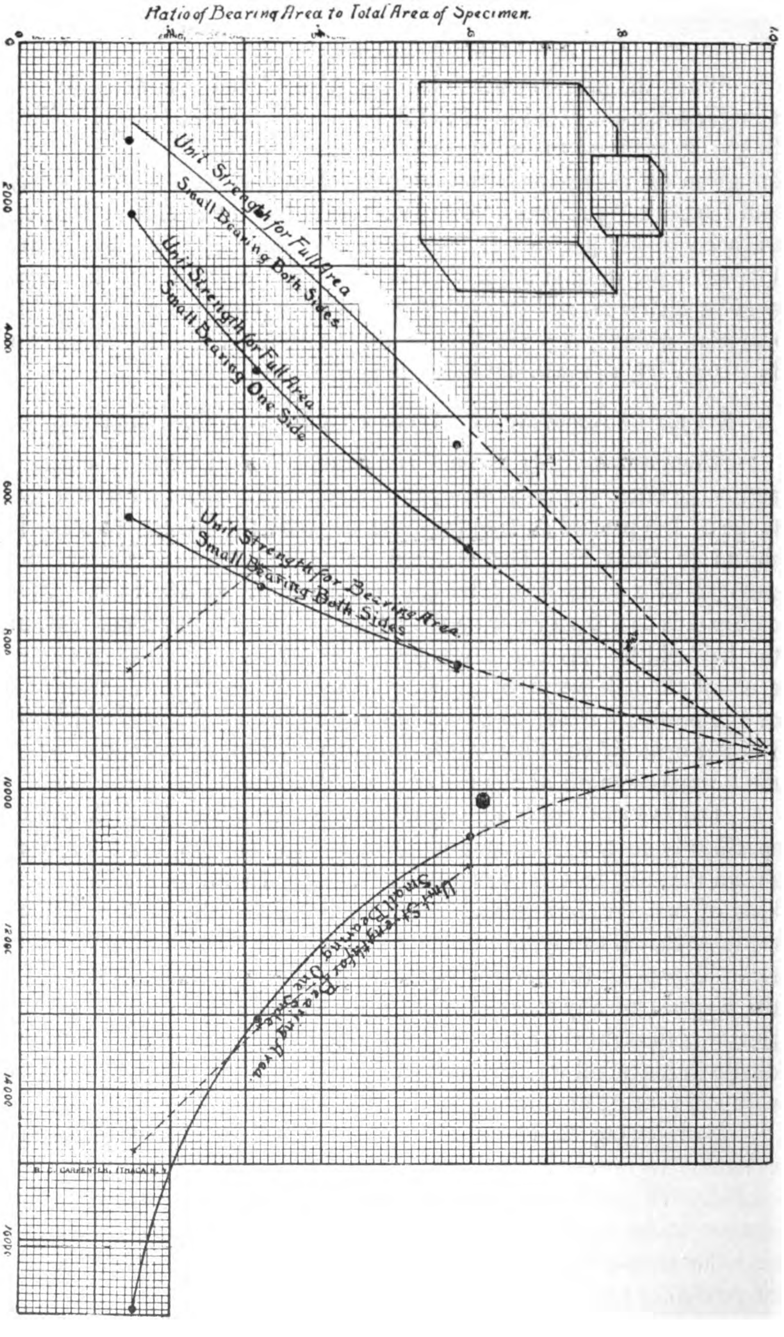

Ratio of Bearing Area to Total Area of Specimen.
0
.2
.4
.6
.8
1.0
2000
4000
6000
8000
10000
12000
14000
16000
Unit Strength for Full Area Small Bearing Both Sides
Unit Strength for Full Area Small Bearing One Side
Unit Strength for Bearing Area Small Bearing Both Sides
Unit Strength for Bearing Area Small Bearing One Side
B. C. CARPENTER, ITHACA N. Y.

PLATE IX.

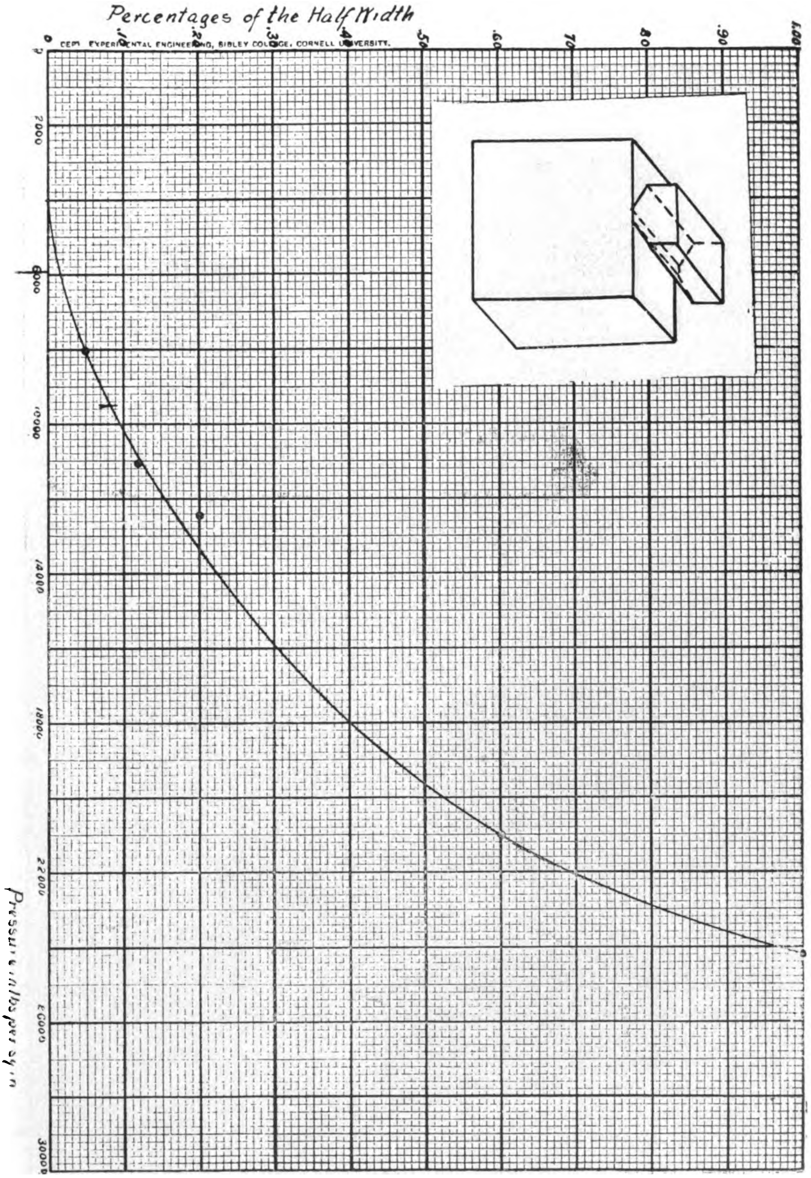
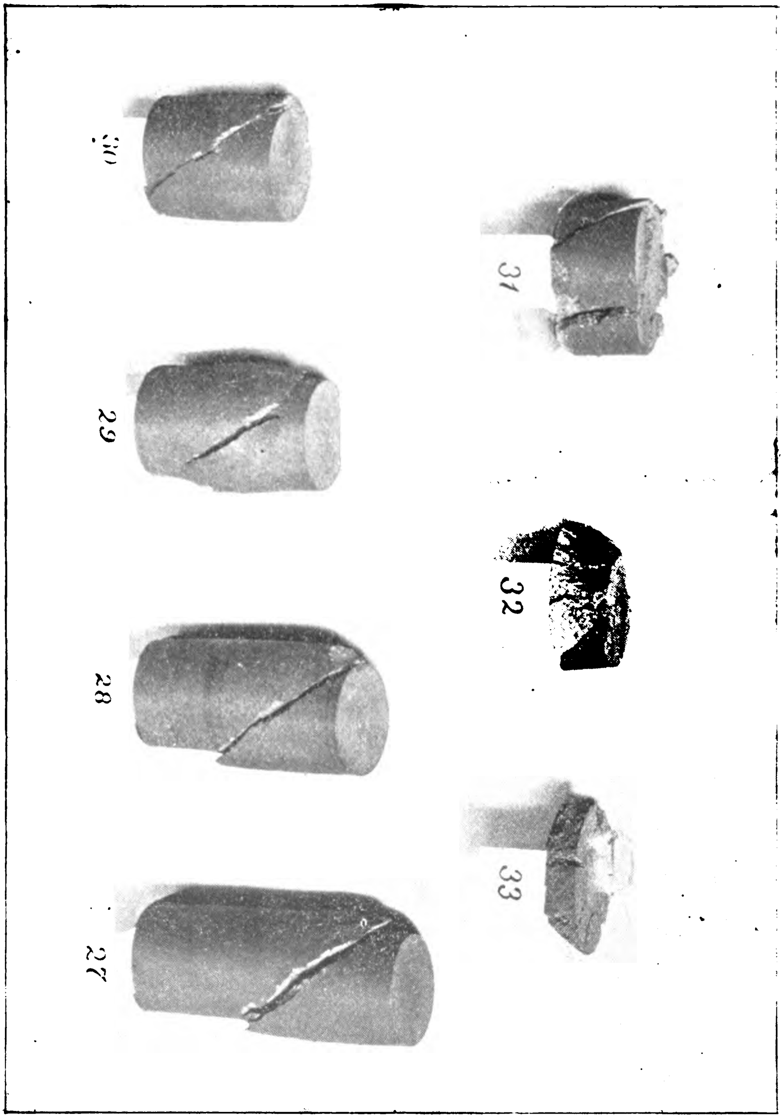

Percentages of the Half Width
CEPT. EXPERIMENTAL ENGINEERING, SIBLEY COLLEGE, CORNELL UNIVERSITY.
0
.1
.2
.3
.4
.50
.60
.70
.80
.90
1.00
0
2000
6000
10000
14000
18000
22000
26000
30000
Pressure in lbs per sq in

PLATE X.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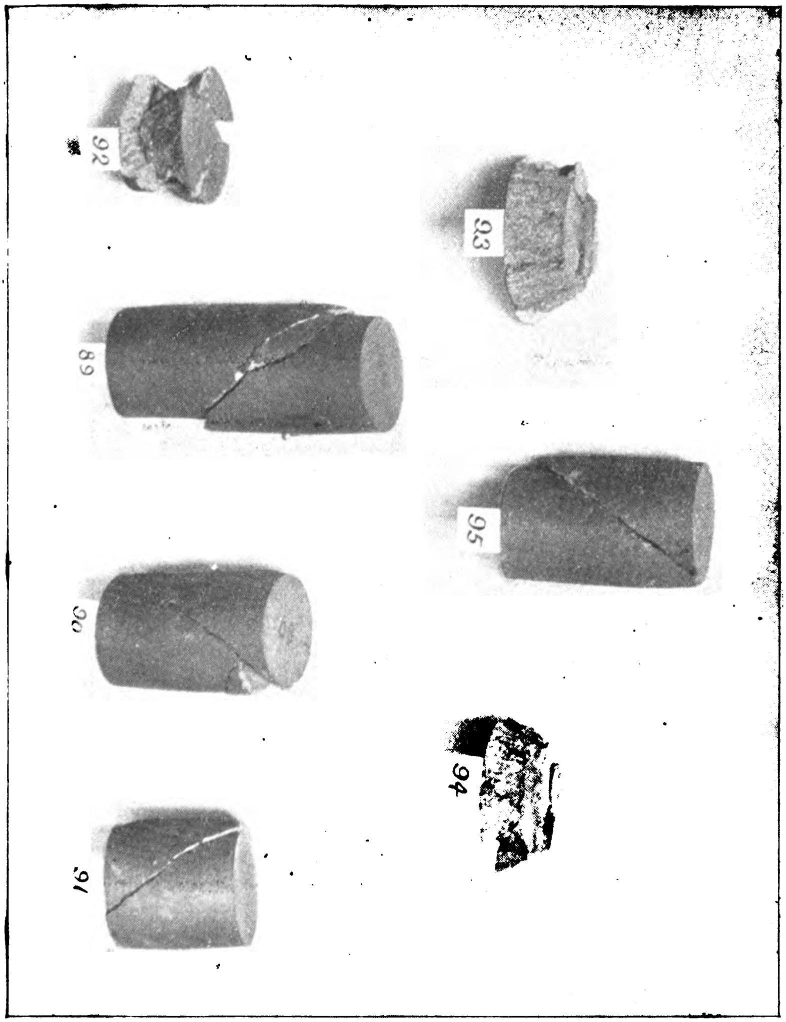
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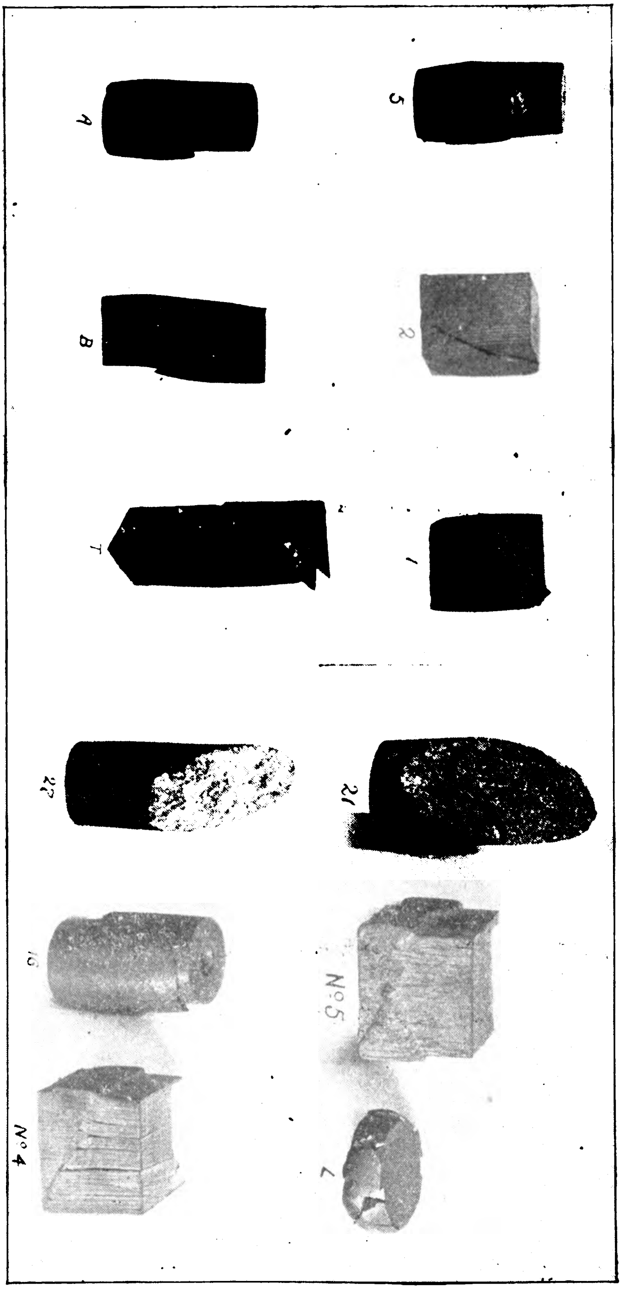
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PROFESSOR TETMAJER'S CRITERION.

By William Kent, New York.

> Just as the valuable qualities of cast iron for all ordinary purposes are best determined by the product of the ultimate strength of a cast-iron beam into its deflection, divided by the volume or weight of the beam, so the working qualities of structural iron or steel are best determined by the area of the strain diagram obtained by plotting a complete tensile test. But the area of this diagram is a very nearly constant portion of the rectangle obtained by multiplying the ultimate strength by the ultimate elongation, If this product (of strength by elongation) therefore be made the criterion of acceptance rather than either the strength or elongation taken separately, or both combined, a wider range of these individual results might safely be used, provided their product remained practically constant. (Prof. J. B. Johnson, in DIGEST OF PHYSICAL TESTS, Vol. I, No. 1, p. 4.)

IT may appear presumptuous to object to the use of the product of strength by elongation as a better criterion for acceptance or rejection of iron and steel than the strength and elongation taken separately, when such a criterion is advocated by such eminent authorities as Professor Johnson in this country, Professor Tetmajer, of Zurich, when it has been adopted by the Swiss and the Austrian Governments, and is, as stated by Professor Johnson, commonly used in Germany. There appears at first sight to be quite a formidable list of authorities in favor of this criterion, and I do not know of any one who has written against it. Possibly it has not been widely published heretofore, and for that reason has escaped criticism, but its appearance now in THE DIGEST OF PHYSICAL TESTS insures it wide circulation. It is now time for it to be subjected to review, so that if it has any good reason for existence its proposers may be induced to show what these reasons are, and if it has not it may speedily receive its quietus.

First, as to the weight of authority in its favor. The Swiss Government adopted it, on Professor Tetmajer's recommendation, some twelve years ago, and the Austrian Government only recently. It has has not been adopted by any department or bureau of government in either England or the United States, by Lloyd's or any other bureau of marine inspection, nor by any practicing or contracting structural engineer, nor is it recommended, as far as I am aware, by any American authority on strength of materials, or by any commercial testing laboratory. Twelve years is a long time, as time now goes in scientific work, and if the criterion had been such a good thing twelve years ago, it would have come into general use by this time. That it has not come into use is presumptive evidence, at least, that it is not a good thing.

Second, as to the criterion itself. I hold that the product of ultimate strength by ultimate elongation of a piece of steel, is not a measure or criterion of any quality of a steel, the knowledge of which quality is useful to the constructor, nor an indication of the nature or kind of steel by which one kind of steel may be distinguished from another. Strength and elongation are two entirely different and unrelated qualities, except so far as they are both found in the same piece of metal, and in some steels they vary in some degree inversely with each other. They differ as widely as do feet and tons, and their product is simply an expression for the work or energy required to break them, and is not an indication of the really essential qualities which the engineer wishes to know, which are: 1. ultimate strength; 2. probable elastic limit, which is to some extent a fraction of the ultimate strength; 3. the ductility, which is expressed by the elongation. Two pieces of steel having identical products of strength and elongation may be, for practical purposes, no more alike than a moving ship and a flying projectile, both of which have the same number of foot-tons of energy.

Suppose we test a piece of steel, whose length is 10 inches between gauge marks and its sectional area 1 square inch. The product of its strength by its elongation, or the "criterion" is 150,000-inch-pounds. Can Professor Johnson, or any one else, tells us from this criterion what kind of steel this is or what it may be used for? It may be any one of a number of different kinds of steel, a few only of which are noted below.

KINDS OF STEEL.	ULTIMATE STRENGTH PER SQ. IN.	ELONGATION. PER CENT. IN 10 IN.	PRODUCT. INCH-POUNDS.
Spring, ...	100,000	15	150,000
Structural, ...	75,000	20	150,000
Boiler-plate, ...	60,000	25	150,000
Rivet, ...	50,000	30	150,000

Again, we may test two other pieces of the same size, and one gives 151,800 inch-pounds and another only 132,000. Shall we assume, therefore, that the first of these pieces is superior quality and the second inferior? We cannot tell till we examine the record of strength and elongation of each. They are:

Spring,	120,000 lbs.;	11%	product, 132,000.
Boiler-plate,	66,000 lbs.;	23%	product, 151,800.

We now find the exact reverse of what we might have been led to believe from an inspection of the products alone. The first, having a high figure for a product, would be rejected by many engineers for boiler-plate as being both too high in tensile strength and too low in ductility, and the second, having a product far lower than the "criterion" of 150,000 inch-pounds, might be considered a very superior quality of spring or tool-steel for certain purposes.

To judge metals by the work done or energy exerted in breaking them, measured in inch-pounds, or product of stretch by elongation, is about as useful, commercially, as valuing a horse by horse power, as we rate engines, or by the product of his tractive force into his velocity. Two horses may be tested on a road, each working so as to show the particular kind of horse quality in which he excels. They each develop one-horse power. The product of their tractive force by their velocity is just 33,000 foot-pounds per minute. Are the two horses, therefore, equal in value? It cannot be told until their records are analyzed to find what was the tractive force and what the velocity of each. It is found that the records are as follows:

Horse A,	tractive force, 13.2 lbs.;	velocity, 2,500 feet per minute.
Horse B,	tractive force, 12.5 lbs.;	velocity, 264 feet per minute.

Horse A is a race-horse, with a rate of a mile in 2 minutes 7 seconds, while horse B is a strong draught-horse. The value of A is determined not by the fact that he can do a horse-power of work, but solely his speed, while that of B depends far more upon his strength than upon his speed.

I am not condemning the addition to test records made for scientific purposes, or in special cases, of the product of strength by elongation, or of the resilience, elastic or ultimate, of a test specimen, for the purpose of comparison with other records, but I do object to its being considered a criterion for the acceptance or rejection of metal, or as good a measure of the quality of metal as the stretch and the elongation taken separately. For commercial purposes it is no more valuable than the long-discarded "strength per square inch of fractured section."

DIAGRAMS SHOWING EFFECT OF ALTERNATE EXTENSIONS AND COMPRESSIONS ON CAST IRON.

By Thomas Gray, Professor of Dynamic Engineering, Rose Polytechnic Institute, Terre Haute, Ind.

IN this note I give a few sample diagrams, which illustrate the effect of slowly applying, alternately, a pull and a push to a bar of cast iron. The diagrams for tension tests are given in Fig. 2, tests 1, 2, and 7, while the diagrams for compression are given in Fig. 1, tests 2, 4, 6, and 8. No diagram was taken for test 5, which was an application of tension of approximately the same amount as that shown in test 3, the object being to get the specimen taken out of the machine and adjusted for compression with as little delay as possible between the tension and compression. The form of the specimen is shown in Fig. 2; it was 27 inches long over all, 25 inches between the shoulders, and 2 inches in diameter. The part on which the measurements were made was 18 inches in the centre of the bar. The iron was soft and light gray in color, having an average strength under tension of about 15,000 pounds to the square inch, and under compression of about 80,000 pounds to the square inch. A diagram showing its behavior under continuous tests to fracture from compression is shown in Fig. 3. The successive loops in this diagram show the effect of allowing the load to decrease slowly to zero, and then immediately afterward the reapplication of the load. The open loops show the dissipation of energy during a cycle. In general, after slowly applying any given load and taking it off again, the iron can be subjected to nearly as much load repeatedly, and the pen of the recording apparatus will follow the same line around the loop. The average rate of applying the load in these tests was about 5,000 pounds per square inch per minute. The diagrams were drawn by the autographic testing machine attachment described in the January number of the QUARTERLY DIGEST.

Referring to the diagrams, Figs. 1 and 2, horizontal ordinates give a measure of the stress applied, and the vertical ordinates of the corresponding change of length. In order to obtain stress in pounds per square inch from the diagrams of Figs. 1 and 2, the horizontal ordinates, measured in numbered divisions, have to be multiplied by 1,429. In order to obtain change of length in inches, per inch length, the vertical ordinates, measured in numbered divisions, have to be divided by 3,476. In order to follow the test in any one case, proceed as indicated by the arrows in the diagram of tests 2 or 7. The test begins with the recording pen at *a*, and load is applied until the pen reaches *b*, the load is then gradually removed, the pen following the line as indicated by the arrow until it reaches no load at *c*. The load is then gradually applied, the pen drawing the line indicated by the arrow, passes through *b* and then continues the original line *a b* at *d*, the application of load is again stopped and decrease begins, the pen, following the down line indicated by the arrow, reaches no load at *e*, then, on the re application of the load, takes the up line, similarly indicated, and so on to the end of the diagram.

It will be observed from these diagrams that the smallest application of tensile stress to a new specimen produces set, a confirmation of the result obtained half a century ago by Hodgkinson. Repeated application of the same load, as shown by the up line of the successive loops, does not sensibly increase the set, but any increase beyond the previous maximum value of the stress produces additional set. A similar result is obtained for the first application of compressive stress, but not so marked as in the case of tension. When we return to the second application of tensile stress, we find that the apparent elastic limit which had been set up by tension has been entirely eliminated, and the specimen behaves very much as if it were a new specimen. In this, again, we have the confirmation of well-known results from the work of several experimenters. Not only is the *quasi* elastic limit entirely removed, but we see from test 7, for example, that the set produced by tensile stress is considerably more rapid after the material has been subjected to compression. Turning attention particularly to the compression diagrams, we find the same general result as to the effect of extension or subsequent compression, namely, that the *quasi* elastic limit obtained by compression is eliminated by extension, and that permanent set takes place more rapidly after extension.

Another interesting point is brought out in test 6, namely, that if the compression takes place immediately after extension the return curve from *c* does not pass through *b* but passes *above* it. The same is the case for *d*, but after greater stress has been applied than the previous maximum, as at *f*, the return curve gives a closed cycle. This result shows rapid recovery of the specimen under load and release of load. It was actually not so short when the load corresponding to the *b* point was applied the second time, as it was on the

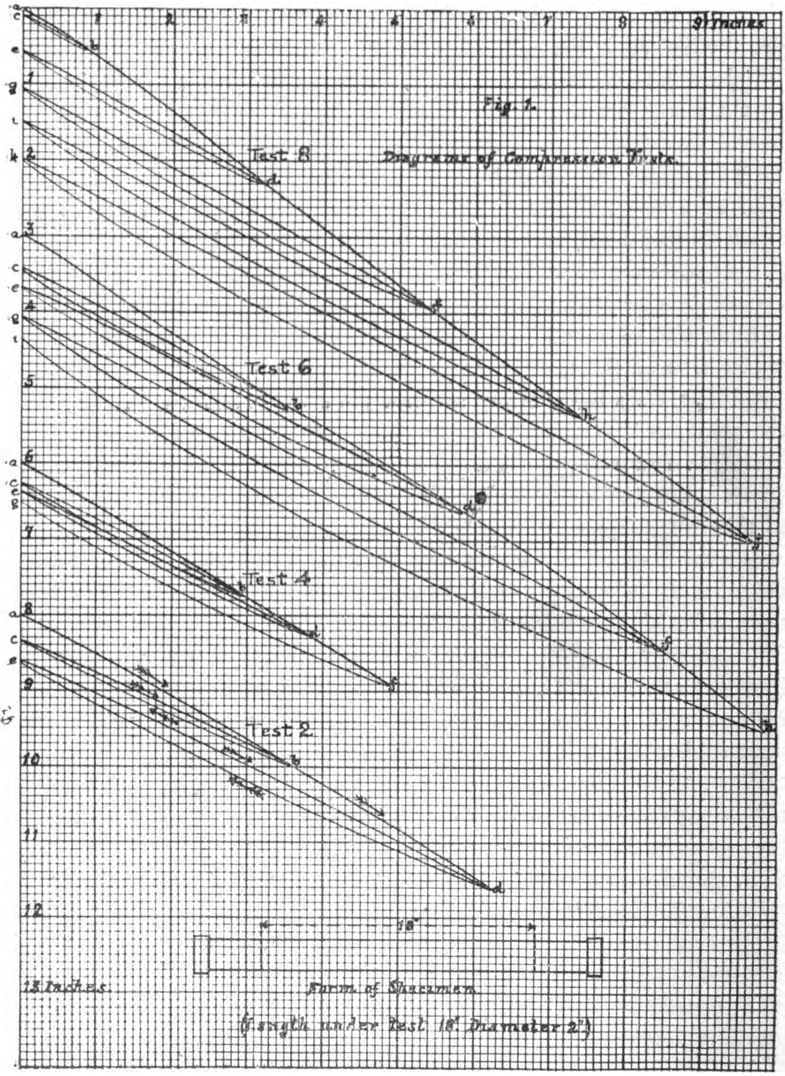


Fig. 1.

Diagrams of Compression Tests.

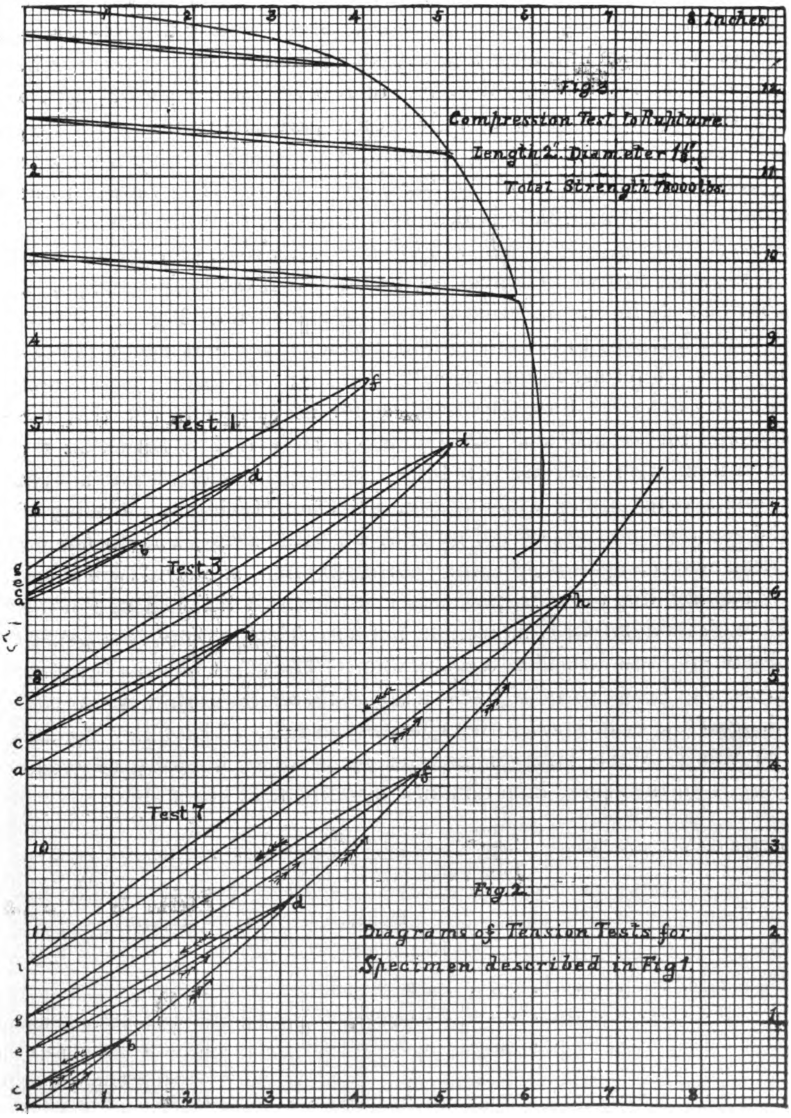


Fig 3.
Compression Test to Rupture.
Length 2". Diameter 1⅛".
Total Strength 78000 lbs.

Fig 2.
Diagrams of Tension Tests for
Specimen described in Fig 1.

first application. This result has been confirmed by tests on other specimens. Compare now the diagrams of test 8 with those of test 6. In this case the end of the specimen broke off under test 7, subjecting the specimen to a sudden shock, and time had to be taken to put the specimen in a lathe and true up the end before test 8 could be made. The result is that the effect of recovery is not shown, with a possible slight exception at *b*, but each part of the test gives very accurately a closed loop to *d*, *f*, *h*, and *g*, the pen returning from *j* to *k* along the same line on release of the load. It is further to be noticed, however, with regard to tests 6 and 8, that the line *a*, *b*, *d*, *f*, *h*, *j*, tends to become concave upwards, after successive alternations of the load, instead of convex, as it would be if the load were applied continuously in one direction to rupture, as shown in Fig. 3.

With regard to the modulus of elasticity, we find a general confirmation of former results, namely, that for small loads the modulus is nearly the same for compression as for as extension, but that the modulus for extension diminishes much more rapidly than that for extension with increase of load. Permanent elongation always diminishes the Young's modulus for extension, taking as the value of the modulus the ratio of the extreme allowable stress, without further permanent elongation, to the corresponding strain. Permanent shortening, due to stress, produces comparatively little change in the Young's modulus for compression, but what change there is is generally an increase instead of a diminution. The effect of cross-bending a cast-iron beam, so as to give it a set, is, therefore, to shift the neutral plane of the beam toward the compression side. The following are the values of the Young's modulus for a stress intensity of 5,000 pounds on the square inch obtained from the tests given above :

TABLE OF YOUNG'S MODULUS FOR EXTREME STRESS OF 5,000 POUNDS PER SQUARE INCH FROM TESTS 1 TO 8.

Test.	Modulus. Pounds per □″.	Remarks.
1	10,340,000	Tension.
2	10,520,000	Compression.
3	9,320,000	Tension.
4	10,160,000	Compression.
5	no record	Tension.
6	9,790,000	Compression.
7	8,630,000	Tension.
8	9,360,000	Compression.

The general effect of repeated alternations of opposite stress is to diminish both the modulus for extension and for compression.

The following table gives the variation of the Young's modulus with varying extreme stresses applied cyclically, as indicated by the curves during the tests 1 and 7. The numbers were obtained by interpolation.

MODULUS.		
Test 1.	Test 2.	Stress per □″.
12,200,000	11,150,000	1,000
11,750,000	10,260,000	2,000
11,280,000	9,600,000	3,000
10,810,000	9,110,000	4,000
10,340,000	8,630,000	5,000
9,870,000	8 280,000	6,000
	7,940,000	8,000
	7,350,000	10,000

PERMEABILITY OF IRON AND STEEL.

The permeability of iron and steel to magnetism has recently been the subject and investigation by M. Osterberg, and although it is a subject concerning which there has been much research, and about which many results have been published, the results of this investigation are worthy of brief notice in the *School of Mines Quarterly*, 1896, Vol. xvii, page 118. Osterberg sums up the causes of variation in the magnetic permeability of iron as follows: Chemical composition, temper, temperature, rapid magnetizing and demagnetizing, and previous history of the specimen. Samples of steel made by the basic open-hearth process, and containing C 0.07, Si 0.053, P 0.008, S 0.032, and Mn 0.22 per cent. are compared with acid open-hearth samples containing C 1.406, Si 0.077, P 0.032, S 0.032, and Mn 0.470. Osterberg obtains permeability curves for each of these metals after ordinary cooling, annealing hardening followed by annealing and hardening alone. Only at temperatures approaching 400° to 600° F. does the iron begin to lose its magnetic properties, the loss being complete to 760°. Rapid magnetization and demagnetization heat the metal and cause loss by "hysteresis," and iron which has been repeatedly magnetized has a slightly increased permeability. It seems to us that in spite of the voluminous search which has taken place upon this subject, both at home and abroad, that there is still room for further work, and that it ought soon to be possible to make some important generalizations, from which working electricians will be able to extract really definite and reliable data.

THE ACTION OF HEAT ON CEMENT.

By J. S. Dobie, Grad. S. P. S.

THE modern tendency toward large and high buildings, with a skeleton structure of steel, has made the question of fire prevention and protection one of the most vital importance to architects, manufacturers, engineers, and builders in general. Countless experiments have been made to devise some means of preventing iron and steel columns and girders from buckling under great heat. Plainly, the only way this can be done is by so protecting the metal that heat cannot come in contact with the metal surface.

Experiments have also been made, and numerous schemes introduced, to devise some means of making a floor between the girders that will withstand the action of fire, and so prevent a fire, even if started, from spreading from one flat to another. Hollow tile, brick, and terra cotta have been tried with indifferent success; and at present the tendency is toward using Portland cement or concrete as a protection for ironwork.

It is not the purpose of this paper to propose or condemn any scheme, or to introduce any new one; but rather to show what really may be expected from a mass of concrete or cement when subjected to great heat. The writer has carefully examined all available literature upon the subject, including books and trade catalogues; and, while many give tests which are claimed to be eminently satisfactory, still, in almost every case, the accounts give such meagre information about the tests themselves as to be almost useless, as far as information is concered, and certainly so as far as comparison with each other are concerned. The information as to the action of the cement itself is, in every case, very meagre; and all the information given refers only to the conduct of the system tested, and no information whatever is given as to its condition afterward.

In making these tests three brands of cement were used—two Canadian brands: "Star," manufactured at Deseronto, and "Samson," from Owen Sound; one foreign brand, "Jossen," of Belgium manufacture. These cements were thoroughly tested for fineness, strength, and "blowing" before using, and were found to be first-class. The "Star" and "Jossen" were comparatively slow-setting, and the "Samson" set very rapidly.

Tests were made upon neat briquettes and sand briquettes, mixed in proportions of one sand to one cement, two sand to one cement, and three sand to one cement. The age of the briquettes varied from two months to about four years. Over two hundred briquettes were used in making the test.

The briquettes were heated in a small assay furnace, heated by a large gas burner, and which gave a range of temperatures of from about 650° F. to about 1775° F.

The temperatures were determined by means of a water calorimeter; the temperature of the furnace being obtained from the rise in temperature of a pint of water, in which had been immersed an iron ball of known weight, and which was heated to the temperature of the furnace. The temperatures given are approximately correct. The calorimeter gave good results—different readings, under the same conditions, rarely differing by more than 10° or 15°, which is very close for such high temperatures.

On heating the briquette and removing from the furnace, the first thing noticed was a loss in weight in the briquette; and almost all neat briquettes showed cracks, some large and some small. Some sand briquettes also showed cracks, but not to the same extent as in the neat briquettes; but there was no exception to the change in weight. This loss in weight is due to the fact that the hardened cement is a compound of hydrated crystals of aluminium silicate and calcium silicate, and the heat drives off the water of crystallization, and the loss in weight corresponds to the amount of water of crystallization driven off by the heat. Now, since the crystals depend upon the water for their formation, it is evident that when the water is removed the crystals are destroyed, and the cement ruined. Such was found to be the case in every instance.

The briquettes, after cooling sufficiently to allow handling, were broken in the testing machine, the load being applied at the rate of about 400 pounds per minute. The result showed a marked decrease in the tensile strength, as reference to Tables I and II will show; and, under the best conditions, this loss in tensile strength showed an approximate proportion to the loss in weight. Briquettes which lost 19 or 20 per cent. of weight, which is practically the amount of water required for proper crystallization, were practically unable to resist any load whatever, and in very few cases possessed 10 per cent. of their original strength.

The effect of different temperatures was rather peculiar. Briquettes placed immediately into a temperature of about 1775° F. showed a very great loss in strength for a very small loss in weight, and did not appear to follow this law of proportion between losses of weight and strength, at least not nearly so well as briquettes treated differently. When the briquettes were gradually heated, however, and allowed to slowly rise to the temperature of the furnace, this law was followed quite closely, as reference to tables will show. The plotted curves give a good idea of the effect of slow and rapid heating on the relation of the cement to this law. This is accounted for by the fact that the cold briquette, on being placed in the furnace at such a great heat, is immediately subjected to very considerable internal stresses, due to the expansion of the outside of the briquette before any water of crystallization at all is driven off. Briquettes, heated gradually, were not subjected to these internal stresses to nearly the same extent as those which were heated very suddenly.

An attempt was made to discover, if possible, a critical temperature to which it would be possible to subject the cement without danger of injury to the crystals, and where the cement would retain its cohesive powers. It was found that, if such a temperature existed, it was below the lowest temperature generated by the furnace, which was considerably below red heat. The lowest temperature had the same effect as the highest, excepting, of course, that with the low temperature a longer time was required to effect the same reduction of weight than with a higher one. The lowest temperature necessary to destroy the cement was not determined, but is probably quite low. The following quotation from Heath's *Manual of Lime and Cement* is interesting regarding this: "Even good Portland cement concrete, if exposed to the weather during a hot, dry summer, with no supply of moisture available, will probably be found covered with a network of innumerable hair-like cracks, which are signs of the beginning of disintegration, the natural and inevitable result of the loss of the water of hydration of the cement." (Heath's *Manual of Lime and Cement*, page 75.)

The only neat briquettes which were not cracked by the heat were some very old ones, about four years old, which were tested. Most of these were uncracked, although some that were very suddenly heated cracked somewhat. All the newer briquettes cracked, the cracks being very large in most cases.

After cooling, the briquettes were found to be quite soft, and could easily be crushed between the fingers. This was especially noticeable in the case of those briquettes which had lost the most water of hydration. These briquettes were like lumps of dry mud or clay, and a very slight pressure was sufficient to crush them completely. Briquettes which had not lost so much water were harder, while those which had lost only about one or two per cent. of water were quite hard. Of this latter class, however, those briquettes which had been heated suddenly were much the softer.

Briquettes which were cracked on removing from the furnace showed the cracks much distended and widened out on cooling, and most of those which had not cracked in the furnace showed cracks on standing for a day or two.

All sand briquettes, whether cracked in the furnace or not, entirely disintegrated on standing in air for a time, the cementing material having been entirely destroyed. Those sand briquettes which had lost most of their water hydration disintegrated first, and those that had lost less followed soon after. Six briquettes of two sand to one cement were placed suddenly in the most intense heat, and left for about three minutes and removed. They lost from three to four per cent. in weight, and two of them which were broken showed a complete loss of tensile strength; one breaking before any load was applied, and the other going at about eight pounds. The remaining four were set away, and in a couple of days commenced to crumble, the edges going first, and leaving an irregular mass in the centre. This, however, resisted for some time, but in about three weeks they also were completely disintegrated. It was thought that the sudden application of very intense heat would cause the water of hydration to be removed from the outside only, and that the inside would remain solid, and resist weathering. The results, however, showed that although the outer part of the briquettes suffered most, as is shown by the rapid disintegration, still the heat also affected the inner part, and caused its ultimate disintegration. These briquettes were too hot to be handled comfortably when weighed, after removal from the furnace, and it is quite probable that the heat still remaining in the outer portion caused a still further loss of water of hydration in the parts in the centre of the mass. The low tensile strength of these two briquettes was probably caused by the sudden heat causing great internal stresses in the briquettes. The parts of the two broken briquettes also behaved in the same manner as the unbroken ones.

A number of briquettes were heated, and rapidly cooled by being immersed in cold water, after being heated for different lengths of time at different temperatures. In every case the briquettes cracked when immersed; and, if they were red-hot before immersion, they completely disintegrated—in most cases being reduced to a heap of soft mud. The sand briquettes acted precisely similar to the neat ones; and it appears conclusive that if cement or concrete is allowed to become red-hot, and is then immersed in cold water, the effect would be ruinous in the extreme. Some briquettes were also heated, and, instead of being immersed, were placed under a small stream of water flowing at the rate of about two litres a minute. The results were the same. Red-hot cement completely disintegrated. In some cases, when heat had not been applied sufficiently long to heat the briquette through and through, and where the edges only glowed, the glowing parts chipped off when water was applied, leaving an irregular mass comprising that part of the briquette which had not been heated so much. Even when not completely disintegrated, this central mass showed cracks, was very soft, and had no strength to resist any pressure.

From these experiments, then, the following conclusions may be drawn:

1. While there is no doubt that a covering of Portland cement concrete will afford some protection to a metal column or girder, still there appears to be no doubt that the concrete itself will be ruined by the action of the fire, and will have to be removed as soon as the fire is subdued. The concrete covering may remain upon the ironwork during a fire, but the heat will damage it to such an extent that it will disintegrate afterward. The impression appears to exist that the concrete will be in as good condition after a fire as before. This is a mistake, as a fire of ordinary intensity is sufficient to ruin, completely, a very large covering of concrete.

2. The concrete covering, if heated, will not stand the action of water; all the experiments show that water applied to hot cement is extremely ruinous. This is a very important point, when we come to consider the immense amount of water thrown into a building during a conflagration. The cement is certain to become red-hot; and then, when the hose is turned on, the water strikes the protecting covering, and it breaks off, leaving the ironwork bare and filling the air with a shower of dangerous falling pieces. In a fireproofed building the usual construction is to have a system of concrete arches and slabs between the joists and girders. The walls are of concrete, and have metal doors to confine the fire, if started, to one spot as much as

possible. The floor is usually cemented over, or boarded with thin flooring, and is, therefore, more or less water-tight. The ceiling, or under part, might be exposed to intense heat, while immense quantities of water were being poured upon the upper portion, causing an immense strain on the concrete, not only from the weight of water, but from the opposite strains which the cement would undergo, on account of one side being expanded by the intense heat, while the other side is kept cold by the water upon it. All this time the fire below is eating away the strength of the cement, and a collapse is the result.

3. In calculating for the design of the columns and girders, and especially for floors, no allowance should be made for the strength of the concrete, but the cement covering should be considered as so much extra load on the system. It is the usual custom, in designing a fireproof system, to consider that the concrete bears its share of the loads upon the girder; and, in a great many cases, the girder is designed on that assumption. If no fire occurs, this is all right; but, during a severe fire, the concrete loses its cohesive properties, both on account of the loss of its water of hydration, and on account of the great internal strains caused by the expansion of one side under heat, and, consequently, becomes unable to resist any stress anywhere near what it was originally able to bear, and in most cases would not even be self-supporting. The experiments have shown that sudden heating is extremely ruinous, much more so than heat gradually applied; and, in the average fire, a very high temperature is generated in an incredibly short time, and concrete subjected to its action would, in a very short time, be unable to bear any strain whatever.

It appears from this that, in a fireproof building, floors should never be constructed of slabs of cement, forming short spans or arches from girder to girder, without any support. If no load were placed on the floor, and it were subjected to heat, it might possibly retain its form, provided water was not thrown upon it; but if loaded, as any floor would be, a collapse is inevitable. Concrete, then, should always have a metal system of some sort imbedded in it, sufficiently to bear the weight of the concrete itself, and all external loads which may come upon it.

The great advantages possessed by cement or concrete, as a fire-protecting material, are its low heat-conducting power and its very small expansion under heat. These advantages, however, are entirely offset by the fact that it loses its strength under heat, is ruined by water applied during a fire, and will disintegrate after a fire, if not during the fire itself. These experiments tend to show, therefore, that the value of concrete as a fire-protecting material has been greatly overestimated, and that disastrous results may follow from confidence in a building protected with such a material.

TABLE I.—RESULTS OF TWENTY-SIX BRIQUETTES HEATED SUDDENLY.

Temperature, 1,775° F. (approx.).

Weight in Grammes.		Per Cent. Lost	Tensile Strength.		Per Cent. Lost.
Before.	After.		Before.	After.	
*140.02	125.57	10.4	530	190	64.1
*139.28	117.47	15.4	"	200	62.3
*140.06	115.75	17.3	"	185	65.1
*139.07	113.72	18.6	"	53	90.0
*140.46	125.99	11.6	"	180	66.1
*140.98	132.87	5.7	"	235	55.7
*139.23	137.68	1.1	"	330	37.7
*140.11	120.89	13.7	"	140	73.6
*139.47	133.57	2.9	"	280	47.1
*139.21	112.07	19.5	"	15	97.1
*140.17	121.17	13.4	"	155	70.7
*138.71	119.70	13.7	"	145	72.7
*135.77	131.70	2.9	930	0	100.0
†133.75	118.85	11.1	"	20	97.8
†132.75	dropped from	tongs, and bro	ke on floor.		
†131.16	123.05	6.2	930	50	94.6
†132.76	118.95	10.4	"	20	97.8
†134.15	128.70	4.8	"	23	97.5
‡139.22	125.72	9.7	515	85	83.5
‡138.41	128.39	7.2	"	75	85.4
‡140.00	134.23	4.1	"	122	76.3
‡137.35	135.54	1.3	"	200	61.2
‡138.47	131.38	5.1	"	97	81.1
‡138.21	135.68	1.8	"	185	64.1
‡140.04	112.87	19.4	"	0	100.0
‡137.26	113.24	17.5	"	10	98.1

* "Star" Brand.

† Briquettes, 4 years old, brand unknown.

‡ "Jossen" Brand.

TABLE II.—RESULTS OF TWENTY-ONE BRIQUETTES HEATED VERY GRADUALLY AND BROKEN.

Maximum Temperature, 1,000°–1,025° F.

Weight in Grammes.		Per Cent. Lost.	Tensile Strength.		Per Cent. Lost.
Before.	After.		Before.	After.	
*139.27	132.34	4.9	530	395	25.6
*138.31	130.16	5.9	"	390	26.3
*140.26	128.32	8.5	"	348	34.3
*140.06	129.16	7.8	"	351	33.7
*138.07	126.23	8.6	"	327	38.2
*138.04	120.13	12.9	"	152	71.2
*139.26	116.27	16.5	"	73	84.3
*138.35	113.31	18.1	"	29	94.5
*140.21	119.26	14.9	"	110	79.0
*139.32	125.34	10.04	"	237	55.2
†137.79	129.32	6.1	515	348	32.3
†139.42	130.26	6.6	"	348	32.3
†140.31	133.58	4.8	"	398	22.6
†139.27	127.31	9.3	"	232	49.0
†140.32	120.15	14.3	"	182	64.7
†138.37	136.32	1.5	"	440	14.7
†139.46	134.31	3.7	"	400	22.3
†140.07	121.31	13.4	"	195	62.3
†139.36	117.26	15.8	"	130	74.6
†140.21	122.31	12.5	"	193	62.4
†139.36	112.60	19.2	"	10	98.0

* "Star" Brand.
† "Jossen" Brand.

BRICKWORK MASONRY.

RESULTS OF TESTS MADE IN THE LABORATORY OF THE SCHOOL OF PRACTICAL SCIENCE, TORONTO, DURING THE SESSION OF 1895–6, BY MESSRS. WRIGHT AND KEELE.

By Jos. Keele, B. A. Sc.

BRICKWORK PIERS.

THE following tests were made with the object of determining the resistance of crushing offered by piers of ordinary brick constructed in the same manner and of the materials as those most commonly used in practice in Toronto. These materials will fairly represent those in use throughout the Province of Ontario.

For this purpose a bricklayer and his assistant were engaged to procure from four different brickyards a quantity of each of their grade of bricks, the bricks being taken from the kiln as they came to hand.

The different bricks used were Kingston Road, first, second, and third quality; Humber, first and second; Yorkville, first and second; Carleton, clinker and first, and Don Valley pressed brick, buff and red.

An individual test of each class of brick was made to determine its crushing strength and absorption. The absorption test was made as follows: The dry brick was carefully weighed, then immersed in water, and at the end of twenty minutes the brick was taken out, the surface water dried off, and again weighed. The brick was again immersed until the total time of immersion was thirty minutes, and again weighed.

This was the longest time allowed in water, having found in former tests of the same nature that the absorption of water by the brick was practically complete in thirty minutes.

The table of absorption is given below:

Kind of Brick.	Weight Dry.		Weight after 20 Minutes in Water.		Weight after 30 Minutes in Water.		Absorption in Ounces.	Absorption in %
	lbs.	ozs.	lbs.	ozs.	lbs.	ozs.	ozs.	
Kingston Road, 1st class,	5	5¾	6	0	6	0	10¼	11.9
" " 2d "	5	5½	6	2¼	6	2¼	12¾	14.9
" " 3d "	5	1¾	6	2¼	6	2¼	14¼	17.1
Carleton Clinker, . . .	5	0¼	5	10	5	10½	10¼	12.7
" 1st class,	5	0½	5	13½	5	13¾	13¼	16.4
Yorkville, . . 1st class,	4	10½	5	11¾	5	11¾	17	22.7
" . . 2d "	4	11¾	6	0	6	0	20¼	26.7
Humber, . . . 1st "	5	7½	6	2½	6	2½	11	12.6
" . . . 2d "	5	8	6	6¾	6	6¾	14¾	16.7
Don Valley Pressed, red,	5	13¾	6	6	6	6½	8¾	9.3
" " buff,	5	0	5	15½	5	15¾	15¾	9.7

To ascertain the crushing strength of each quality of brick, two fair and sound samples were selected and bedded between thin layers of Portland cement, thus giving two parallel planes without injury of any kind to the brick.

The following table shows the crushing strength of the different bricks used:

Ultimate Crushing Strength of Common and Pressed Brick.

Class of Brick.	Height.	Area Exposed to Crushing in Inches.		Ultimate Load in Pounds.	Crushing Strength in lbs. per sq. inch.
Kingston Road, 1st class,	2½	8¾ x 4	35	132,400	3.783
" 2d "	2½	9 x 4⅛	37	62,000	1,670
	2½	8⅞ x 4⅛	36.6	63,000	1,721
" 3d "	2⅝	9 x 4⅛	37	67,600	1,821
	2⅝	8⅞ x 4⅛	36.6	68,000	1,857
Carleton Clinker, ...	2½	8⅝ x 3⅞	33.4	190,000	5,685
" 1st class,	2½	8¾ x 4	35	112,000	3,200
Yorkville, . . . 1st "	2⅝	8⅝ x 4	34.5	160,000	4,637
" . . . 2d "	2½	8¾ x 4	35	107,000	3,057
	2½	8¾ x 4	35	112,000	3,200
Humber, . . . 1st "	2¼	8⅞ x 4	35.5	43,400	1,222
	2½	8⅝ x 4	34.5	50,000	1,449
" . . . 2d "	2½	8⅞ x 4¼	36.6	72,000	1,966
	2½	8⅞ x 4¼	36.6	64,000	1,748
Don Valley . . . . red,	2⅜	8⅜ x 4	34.3	184,000	5,372
" . . . . buff,		8½ x 4⅛	35	125,000	3,571

The piers were built by a skilled bricklayer, who also provided the lime mortar, which consisted of 4½ yards of Bloor street coarse sand to 10 barrels of lime, this being about the proportion of two parts sand to one part lime. The cement mortar was mixed in the proportion of three parts sand to one part of good Portland cement. While the piers were being built, two cubes of each class of mortar were prepared and set aside for the purpose of ascertaining their resistance to crushing, thus giving a complete record of all the materials used.

Ultimate Crushing Strength of Mortar 2½ Months Old.

Class.	Height. Inches.	Area Exposed to Crushing in Inches.		Ultimate Load in Pounds.	Crushing Strength in lbs. per sq. inch.
Lime mortar—2 to 1, . .	5	4⅝ x 4⅞	22.5	1,200	53
Lime mortar—2 to 1, . .	4⅞	4⅝ x 4¾	22	1,700	77
Cement mortar—3 to 1, .	5	5 x 5	25	33,800	1,352

The piers were built and laid aside to harden in the mechanical laboratory of the School of Practical Science, in a temperature which averaged about 60° F., and were prepared for the test as follows: A thin mortar of neat cement was spread on a smooth cast-iron plate, and the pier placed upon the mortar and left until the cement hardened. The bottom bed was then trimmed off flush with the sides, the pier placed on the testing machine, and a layer of neat Portland cement mortar was placed on top, the pier was slid under the head of the machine, and the head was brought to its bearing while the mortar was yet soft.

This method ensured two parallel beds and gave a uniformly distributed stress on the pier. The load was applied slowly and continuously, until complete failure of the pier occurred.

Pier No. 1:

Description,	Humber, 1st class, laid in lime mortar ⅜″ joints.
Size of pier, 9″x9″,	area, 81 square inches.
Length, 24 courses,	73 inches.
Age,	10 days.
Ultimate load,	23,600 pounds.
" strength per square inch,	291 pounds.
" " " foot,	20.9 tons.

This pier was built on the testing machine; with lime mortar on top and bottom bed; the head of machine was brought down to a level bearing, and pier allowed to harden in position for ten days.

The pier failed by spreading a little at the head, a wide crack running down the centre to about half the height of the pier.

Pier No. 2:

Description	Kingston Road, 1st class, laid in lime mortar with ⅜″ joints.
Size of pier, 8⅞″x8⅞″,	area, 78.75 square inches.
Length, 8 courses,	23 inches.
Weight,	114 pounds.
Age,	2½ months.
Ultimate load,	44,000 pounds.
Crushing strength per square inch,	558 pounds.
" " " foot,	40.2 tons.

The pier sustained a high load without sign of fracture, but was completely destroyed under the ultimate load.

Pier No. 3:

Description,	Kingston Road, 2d class, laid in lime mortar with ⅜″ joints.
Size of pier, 9″x9″,	area, 81 square inches.
Length, 8 courses,	24 inches.
Weight,	114 pounds.
Age,	2½ months.
Ultimate load,	22,000 pounds.
Crushing strength per square inch	Not determined by experiment.
" " " foot,	

The bottom bed used in this case was the one inch board upon which the pier was originally built; the board appeared to be slightly warped, and split under the application of the load, causing a variation in the stress, to which is due the early failure of the pier.

Pier No. 4:

Description,	Kingston Road, 3d class, laid in lime mortar with ⅜″ joints.
Size of pier, 9″x9″,	area, 81 square inches.
Length, 8 courses,	24 inches.
Weight,	110 pounds.
Age,	2½ months.
Ultimate load,	24,000 pounds.
Crushing strength per square inch,	296 pounds.
" " " foot,	21 3 tons.

Failure occurred by splitting of the bricks in the upper courses, then wide vertical cracks opened throughout the whole length, and under highest load every brick in the pier was shattered.

Pier No. 5:

Description,	Humber, 1st class, laid in lime mortar.
Size of pier, 9″x9″,	area, 81 square inches.
Length, 8 courses,	24 inches.
Weight,	122 pounds.
Age,	2½ months.
Ultimate load,	28,000 pounds.
Crushing strength per square inch,	346 pounds.
" " " foot,	24.8 tons.

The pier held well together until near the ultimate load, then long continuous cracks appeared, with final rupture of the whole pier.

Pier No. 6:

Description,	Humber, 2d class, laid in lime mortar.
Size of pier, 8¾″x8¾″,	area, 76 5 square inches.
Length, 8 courses,	23½ inches.
Weight,	118 pounds.
Age,	2½ months days.
Ultimate load,	22,400 pounds.
Crushing strength per square inch,	293 pounds.
" " " foot,	21 tons.

All the bricks in the upper portion were completely shattered, the principal failure occurring along one corner of pier.

Pier No. 7:

Description	Carleton Clinker, laid in lime mortar with ⅜″ joints.
Size of pier 8⅝″ x 8⅜″,	area, 72 square inches.
Length, 8 courses,	22 inches.

Weight,	114 pounds.
Age,	2½ months.
Ultimate load,	44,000 pounds.
Crushing strength per square inch,	609 pounds
“ “ “ foot,	43.8 tons.

The pier failed, with continuous lines of fracture up and down the four sides, only one brick on the lower bed being uninjured after the test.

Pier No. 8:

Description	Carleton, 1st class, laid in mortar with ⅜″ joints.
Size of pier, 8¾″ x 8¾″,	area, 76.5 square inches.
Length, 8 courses,	23½ inches.
Weight,	110 pounds.
Age,	2½ months.
Ultimate load,	41,000 pounds.
Crushing strength per square inch,	535 pounds.
“ “ “ foot,	38.5 tons.

The pier was completely shattered under the highest load. The mortar crumbled out like sand, and had very little effect in holding any portions of the pier together.

Pier No. 9:

Description	Yorkville, No. 1, white brick, laid in lime mortar with ⅜″ joints.
Size of pier, 8¾″ x 8¾″,	area, 76.5 square inches.
Length, 5 courses,	14½ inches.
Weight,	65 pounds.
Age,	2½ months.
Ultimate load,	39,000 pounds.
Crushing strength per square inch,	509 pounds.
“ “ “ foot,	36.6 tons.

Small cracks appeared as the load was put on. As the highest load was approached portions of the side of the pier spalled off, and finally shattered to fragments under the highest load.

Pier No. 10:

Description	Yorkville white brick No. 2, with pinkish shade, laid in lime mortar with ⅜″ joints.
Size of pier 8¾″ x 8¾″,	area, 76.5 square inches.
Length, 8 courses,	23½ inches.
Weight,	105 pounds.
Age,	2½ months days.
Ultimate load,	30,000 pounds.
Crushing strength per square inch,	392 pounds.
“ “ “ foot,	28.2 tons.

Fine cracks appeared early in the test, which increased to long vertical cracks, running the length of the pier, portions of the brick spalled off, and under the highest load given above the pier was totally destroyed.

Pier No. 11:

Description . .	Don Valley pressed brick, buff color, laid in lime mortar.
Size of pier, 8⅝″ x 8⅝″,	area, 74.4 square inches.
Length, 8 courses,	21 inches.
Weight,	97 pounds.
Age,	2½ months.
Ultimate load,	51,000 pounds.
Crushing strength per square inch,	686 pounds.
“ “ “ foot,	49.4 tons.

As the highest load was approached, fine cracks appeared, which were confined to individual bricks, and were not continuous down the length of the pier; the fracture was rather of a crumbling nature.

Pier No. 12:

Description . .	Don Valley pressed brick, red color, laid in lime mortar.
Size of pier, 8½″ x8½″,	area, 72.25 square inches.
Length, 8 courses,	21½ inches.
Weight,	110 pounds.
Age,	2½ months.
Ultimate load,	88,000 pounds.
Crushing strength per square inch,	1,218 pounds.
“ “ “ foot,	87.7 tons.

The failure of this pier was of somewhat the same nature as that of the last, but the brickwork held together better under the ultimate load.

CEMENT PIERS.

Pier No. 13:

Description, . . .	Yorkville, 1st class, white color, laid in cement mortar.
Size of pier, 8⅝″ x 8⅝″,	area, 74.4 square inches.
Length, 8 courses,	24 inches.
Weight,	110 pounds.
Age,	2½ months.
Ultimate load,	79,000 pounds.
“ “ per square inch,	1,062 pounds.
“ “ “ “ foot,	76.5 tons.

The pier held together well, and did not show much sign of failure until the highest load was reached; the pier was destroyed in the test, probably owing to the brittle nature of this brick.

Pier No. 14:

Description,	Yorkville, 2d class, color white with pink tint, laid in cement mortar.
Size of pier, 8¾″ x 8¾″,	area, 76.5 square inches.
Length, 8 courses,	24 inches.
Weight,	111 pounds.
Age,	2½ months.
Ultimate load,	78,000 pounds.
" strength per square inch,	1,018 pounds.
" " " foot,	73.3 tons.

This pier was well built, and shows the value of a cement mortar for laying brickwork, as its binding qualities allows the brick to develop nearly its full strength.

Pier No. 15:

Description,	Humber, 2d class, laid in cement mortar.
Size of pier, 9″ x 9″,	area, 81 square inches.
Length, 8 courses,	24 inches.
Weight,	124 pounds.
Age,	2½ months.
Ultimate load,	91,600 pounds.
" strength per square inch,	1,131 pounds.
" " " foot,	81.4 tons.

Fine cracks occurred in some of the bricks only under nearly the highest load, but total destruction of the pier took place under the ultimate load, but did not shatter so badly as in the case of those laid in lime mortar.

Pier No. 16:

Description,	Kingston Road, 2d class, laid in cement mortar.
Size of pier, 9″ x 9″,	area, 81 square inches.
Length, 8 courses,	23½ inches.
Age,	2½ months.
Ultimate load,	69,000 pounds.
" strength per square inch,	852 pounds.
" " " foot,	61.3 tons.

This pier held together even under the ultimate load, the failure occurring through actual crushing of some of the upper bricks. After pier was removed from the machine, only small portions of it could be forced away from the mass.

Pier No. 17:

Description,	Carleton Clinker, laid in cement mortar.
Size of pier, 8½″ x 8½″,	area, 72.25 square inches.
Length, 8 courses,	22¾ inches.
Weight,	115 pounds.
Age,	2½ months.
Ultimate load,	174,000 pounds.
" strength per square inch,	2,408 pounds.
" " " foot,	173.4 tons.

Fine cracks appeared toward the end of test; these cracks were not continuous down the length of pier, nor did they increase much in width under the highest load.

Pier No. 18:

While working on this pier the friction clutch of the machine gave way, and the tests were discontinued for the present.

WORKING TO THE DRAWING.

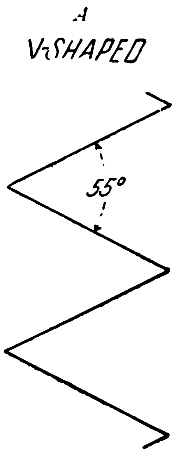
A French blacksmith was once employed by the writer to make some very intricate work, large and small, for a special machine then in progress of construction. One of the plain pieces was a shaft twenty feet long with two collars welded on. The drawing showed a break between collars, because of its length. This puzzled the man considerably, for he knew strict orders had been given him to make it like the drawing. Not having been used to drawings, and having a reverential respect for obedience, he broke it like the drawing, mumbling at the time semi-distinct familiar French adjectives. When the writer returned, after a few days' absence, to note the progress made, he saw an expression on the blacksmith's face ever to be remembered, and which needed no explanation as to its cause. He was one of nature's finest workmen, and had he followed his own ideas, neither he nor the shaft would have had a break.

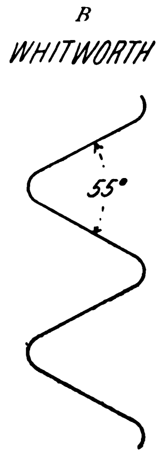
STRENGTH OF ELECTRIC-WELDED FLANGES.—An eight-inch iron pipe ¼-inch thick, with flanges electrically welded on, when tested to destruction at Lloyd's Proving House, Netherton, England, broke in the body of the pipe at 88 tons, the welded part remaining intact, and a similar pipe of steel broke in the welded part of the flange at over 101 tons. These tests were tensile only, and were carried out with the view of proving the absolute soundness and consequent strength of the flanges electrically welded on.

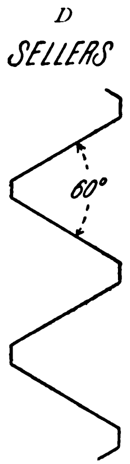
THE INFLUENCE OF THE FORM OF THE THREAD ON THE STRENGTH OF SCREW-BOLTS.

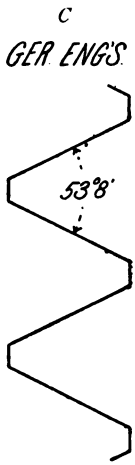
Synopsis of a Series of Experiments by Professor A. Martens, of the Royal Testing Laboratory at Charlottenburg, Germany, given in the Zeits. d. Ver. Deuts. Ing., for April 27th, 1895. Abstracted by Professor J. B. Johnson.

THESE experiments were undertaken at the suggestion of the German Society of Civil Engineers. Two grades of mild steel were used for these bolts, all of which were cut from round bars originally 35 mm. (1.4 in.) in diameter. The softer material, having a tensile strength of 53,500 pounds per square inch, was used for screw-bolts approximately one inch in diameter, and the harder material, having a tensile strength of 62,000 pounds per square inch, was used for the screw-bolts, which were reduced to approximately one-half inch in diameter. Four such bolts were made of each of these sizes for each of the four styles of thread shown in Figs. 1 to 4, making in all 32 bolts with screw threads which were tested. Two of each of these sets were tested in plain tension, the pulling force being applied to the inner face of the nut at one end, and increased until rupture occurred. The other two bolts of each set were tested also in tension, but under a torsional action resulting from the









continuous turning of the nut as the load increased to rupture. In this case the distortion resulting from the permanent elongation of the bolt, was nearly all taken up by the movements of the testing machine, the distortion taken up by the turning of the nut being the least possible to maintain a continuous torsional action at this point.

The same bars were also tested as plain tension test specimens with cylindrical bodies, and again with grooves turned into them, of the same shape as the corresponding screw-threads, leaving the same diameter at the bottom of the groove as obtained at the base of the threads. The actual and comparative average results of all of these tests are given in the following table, from which the following conclusions may be drawn:

1. When subjected to plain tension both the screw-threads and the grooved sections were stronger than the plain bars of the same net area of cross-section, this excess of strength having an average value of about 14 per cent. This excess of strength is due to the re-enforcing action of the shoulder in the case of the groove, and of the threads themselves in the case of the screw.

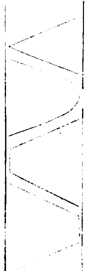
2. There is no very marked difference in the average strength of the bolts on which the several styles of thread were cut, the perfectly sharp groove shown in Fig. 1 being slightly stronger than the others.

3. The weakening effect of the turning of the nut under stress at rupture is much less than might have been predicted, when the distortion of the screw below the nut by permanent elongation is taken into consideration. The tests indicate for this case a strength of the one-inch bolts about 20 per cent. less than that of the plain bars, and of the one-half inch bolts about 15 per cent. less than that of the plain bars.

4. In general it may be said that the turning of the nut upon the bolt at rupture reduces the strength of the net section of the bolt by about 30 per cent.

5. It is very probable that the four forms of screw-threads here shown would show very different results under fatigue tests from repeated stresses. Under such tests it is probable that the sharp re-entrant angle shown in Fig. 1 would develop incipient cracks much earlier than either of the other forms, and that probably the Whitworth thread, shown in Fig. 2, would be the last to develop this kind of weakness. No such tests have as yet been made. It is to be hoped that this subject will soon be investigated, as it is of far more importance than the mere matter of static strength.

SYNOPSIS OF RESULTS: MEAN BREAKING STRENGTH IN POUNDS PER SQUARE INCH.

KIND OF THREAD.	FORM OF BASE OF THREAD.	DIAM. = 1 INCH.								DIAM. = ½ INCH.							
		Stress Applied by			Proportion.					Stress Applied by			Proportion.				
		Machine.		Nut.	Test Bar = 100.			f_g=100		Machine.		Nut.	Test Bar = 100.			f_g=100	
		Grooved	Threaded	Threaded						Grooved	Threaded	Threaded					
		f_g	f_{sa}	f_{sb}	f_g	f_{sa}	f_{sb}	$f\frac{sa}{g}$	$f\frac{sb}{g}$	f_g	f_{sa}	f_{sb}	f_g	f_{sa}	f_{sb}	$f\frac{sa}{g}$	$f\frac{sa}{sb}$
(*a*) Sharp under 55°, ...		62,430	61,580	49,920	116.8	115.2	93.4	98.9	80.0	71,100	70,400	62,720	114.9	114.0	101.4	99.2	88.2
(*b*) Whitworth, ...		62,160	61,300	44,800	116.2	114.6	83.8	98.9	72.2	67,000	69,400	58,880	109.4	112.2	95.2	100.3	86.9
(*d*) Sellers, ...		60,300	60,020	52,330	112.8	112.2	97.9	99.6	86.9	70,250	68,120	62,720	113.6	110.1	94.5	96.9	83.2
(*c*) German Society of Eng'rs,		60,730	61,160	47,640	113.6	114.4	89.1	100.7	78.6	69,260	73,670	62,720	112.0	119.1	101.4	106.4	90.8
(*e*) Normal Test Bar, ...			53,480				100				61,860				100		

EFFECT OF ALTERNATE EXTENSION AND COMPRESSION ON SOFT BAR IRON.

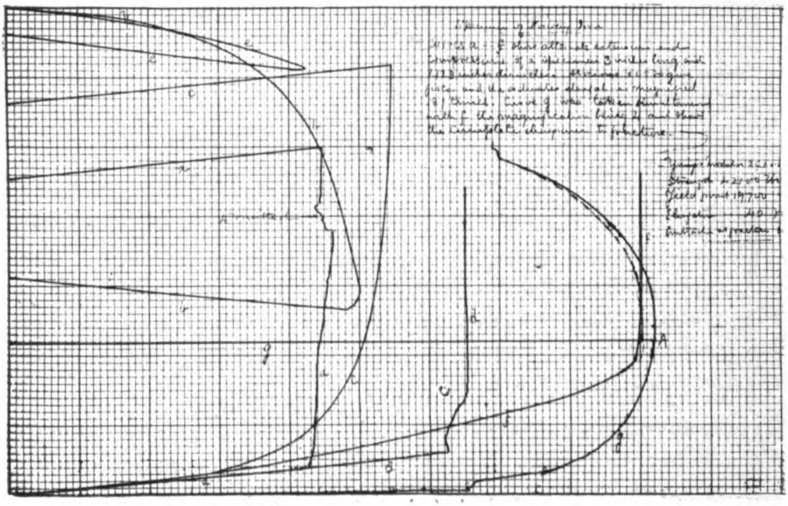
Continuation of Paper on Cast-Iron, by Prof. Thomas Gray.

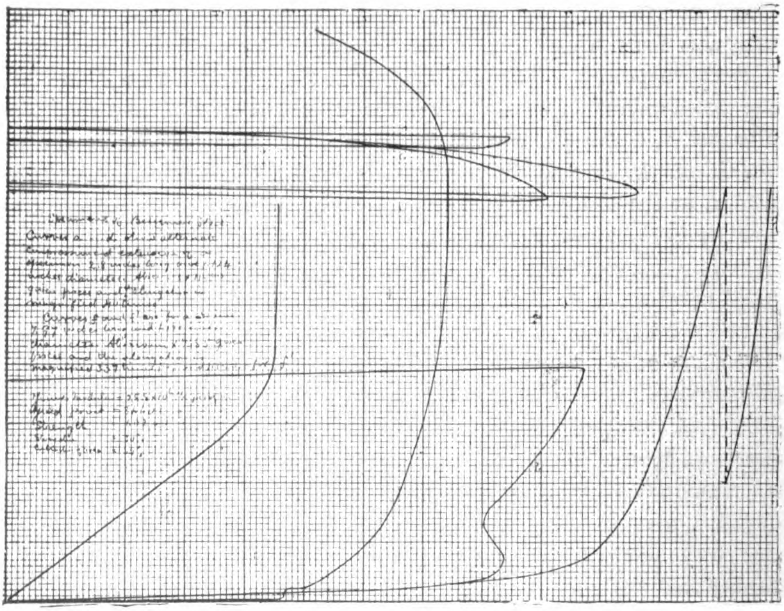
THE diagrams *a–g* of Fig. 4 illustrate the effect of alternately subjecting a bar of soft Norway iron to extension and compression beyond its yield point. This sample of iron from which this short specimen was taken is very soft and of somewhat low tensile strength. The following data, derived from tests on longer specimens, indicate its average quality:

Tensile strength per square inch, ...	42,000 pounds.
Tension per square inch at yield-point, ...	20,000 pounds.
Elongation to rupture, ...	40 per cent.
Contraction of area at fracture, ...	69 per cent.
Young's Modulus of Elasticity, .	29.4x106 pounds per square inch.

It will be observed that the elongation and contraction of area are both high, both exceeding the values commonly obtained from Bessemer steel of good quality. The constants obtained from the diagrams from which Fig. 4 was traced agree closely with the numbers above quoted. The scales to which the diagrams were drawn by the autographic apparatus were, for diagrams *a* to *f*, 187 to 1 for elongation, and 4,580 pounds to the inch for force. For diagram *g*, which was drawn simultaneously with *d* and *f*, the elongation scale is 4 to 1, or the elongations as given by the ordinates of diagram *g* are four times the actual elongation of 3 inches of the bar.

The first experiment is illustrated by diagram *a* which shows the yield-point abscissa about 4.3 inches. The elongation was carried to about 0.043 inches, after which the load was gradually removed. The curve of elastic recovery is nearly straight, but it is considerably steeper than the curve obtained during the application of the load. This is a point of considerable importance in connection with the determination of the elastic constant of iron and steel. It is not an uncommon practice to slightly stretch a specimen so as to extend the elastic limit (not the yield-point), and then measure the elongation due to the removal or re-application of the load. I find almost uniformly that the material does not attain its normal elastic constant for


a
b
c
e
f
g
A
d
Yield point 19700
Elongation 40


Curves a
Strength
h
f

some time after stretching. This general subject, however, will have to be left for discussion at another time.

The second experiment is illustrated by the diagram marked *b*. In this case the specimen was subjected to compression, and it will be noticed that there is no definite elastic limit. The maximum compressive force was about 23,000 pounds, which produced a total compression on the scale of the diagram of 4.34 inches or an actual shortening of the 3 inches by 0.023 inches.

The third experiment is illustrated by diagram *c*. This was an extension, and shows that the elastic limit has been greatly reduced if not entirely eliminated by the previous compression. The elongation in this case was about 0.025 inches, a little greater than the previous compression. The curve for relief of tension represented by the top of the diagram is nearly straight. The specimen was then allowed to rest for a day, and the experiment repeated. The result is shown in diagram *d*. The part of this diagram which represents elastic yielding coincides with the corresponding part of *a*, so far as it goes, and a noticeable feature of *d* is the increased tension which is now required to produce permanent elongation of the material and the abrupt yield-point. Curve *g*, up to the point A, is included in this experiment, so that curve *d* only shows a small part at the beginning. The total elongation produced on the 3 inches was, as shown by *g*, about 0.55 inches.

The fourth experiment was the application of compressive force as represented by diagram *e*. The total amount of the compressive force was comparatively small, but was enough to give a slight permanent set. It is to be observed that the effect of the half-inch of stretch previously given to the iron does not affect its compressive resistance nearly as much as did the very slight stretch given to it in the first experiment. This has been very generally observed by the present writer in numerous observations. The material seems to be much more sensitive to change of elastic properties when it first begins to yield to the load, or at least when the elongation is within the region of the sharp notch in the test diagram, which indicates the yield-point. Elasticity is, however, rapidly recovered with time whether a load is left on the material or not.

The fifth experiment was the application of tension, which was continued up to the rupture of the specimen. Curve *f* shows the semi-elastic and the initial yield-point of the diagram. It will be noticed that, strictly speaking, the elastic limit has again disappeared, but that there is still a definite point of yielding. The tensile strength has, however, been reduced by the application of the compressive stress in the fourth experiment. The full line *g*, continued through A, is ideal as to what would probably have been the diagram, had it been completed in the fourth experiment. The dotted line shows the actual diagram obtained.

EFFECT OF ALTERNATE COMPRESSION AND EXTENSION ON BESSEMER STEEL.

The diagrams in Fig. 5 give an example of a similar set of experiments to those just discussed for iron, the material in this case being a bar of soft Bessemer steel. The part under test formed 2.8 inches in the centre of a test bar. This central portion was reduced to 1.125 inches diameter from a bar 1.475 inches diameter. The ends were left full size, cut normally to the axis of the cylinder for convenience in compression experiments, and were left long enough so that they could be gripped in the usual way for the tension experiments. Diagrams *a* to *e* of Fig. 5 show the results of the experiments referred to in the heading of this section, and diagrams *f* and *f′* show a complete test on an 8-inch specimen of the same bar. In all the diagrams ordinates give elongation and abscissæ force applied. In diagrams *a* to *e* the elongation is magnified 40 times, while the force is 4,580 pounds to the inch of abscissæ. In diagram *f* the elongation is magnified 337 times, and in diagram *f′* 4 times, while in both the force is 7,485 pounds per inch of abscissæ. The data derived from tests *f* and *f′* are given in the figure.

The first experiment in this case was a compression just past the yield-point, which is found to be about 39,000 pounds to the square inch. The total compression produced was only 0.005 inch on the 2.8 inches.

The second experiment was an application of tension. This showed the yield-point to be slightly lower than for compression and that the line of elastic yielding curved gently into the yield-curve. The specimen becomes somewhat weaker just after the first stretch, but with comparatively small total stretch and no irregular jagging of the curves, it begins to strengthen. Similar characteristics are shown in curves *f* and *f′* for the longer specimen, which are even more regular at the yield-point. The elastic limit is rendered somewhat indefinite by the compression, but the effect is not very marked for the first 20,000 pounds' pull. The total elongation produced in this experiment was 0.095 inches.

The third experiment is illustrated by diagram *c*, which shows curvature practically from the beginning of the application of stress. It thus appears that in steel, as well as in cast and wrought iron, the application of sufficient stress to produce set in one direction extends the elastic limit for that kind of stress, but more or less completely eliminates the elasticity against others in the opposite direction. The amount of compression produced in this experiment was only 0.026 inch.

The fourth experiment was a repetition of tension, and is illustrated by the diagram *d*. The first part of the curve coincides with the first part of *b*, and the remainder shows a gradual change of length with increasing stress. The elongation was 0.29 inches, or about ten per cent. of the length of the test piece.

The fifth experiment was a repetition of compressive stress with the object of determining whether the very considerable elongation produced in the previous experiment had produced a similar change in the resistance to compression to that which was observed for large elongations in the case of iron. The result is shown in diagram *e*, which, except at the beginning, lies far above curve *c*, thus showing the same result as was obtained with iron. It thus appears that for iron and steel a slight permanent elongation or compression, produces a much more marked effect on the elasticity against compression or elongation than a large elongation or compression, which seems rather to produce a new bar of approximately normal character. The effect of time on the elastic resistance in one direction, after permanent set in the opposite direction, has not yet been fully investigated, but will probably yield interesting results.

MOBILITY OF MOLECULES IN CAST IRON.

PHILADELPHIA, May 29th, 1896.

EDITOR "THE DIGEST:"

I have been much interested in the article on "The Mobility of Molecules of Cast Iron," by Mr. Outerbridge, republished in your April number, and, although the facts presented are undoubtedly an important contribution to our knowledge of cast iron as affected by physical treatment, the experiments seem to me incomplete, and I hope they may be extended to demonstrate more clearly the theory advanced, or bring out more clearly the objections that may be urged.

By numerous tests Mr. Outerbridge has apparently established the fact that, in a certain way, cast iron is strengthened by repeated shocks, and he assumes, in explanation, that the result is due to a relief by this means of internal strains, the process being considered as a method of mechanical annealing. Unfortunately, however, the tests were all made on transverse specimens, and, although the importance of a direct tensile test was no doubt realized, nothing has yet been reported in that direction.

There is room, therefore, for more light on the subject, and it is to be hoped that Mr. Outerbridge will be able to extend his researches in this direction, for it seems to be quite possible, and even probable, that the gain in transverse strength from rumbling may be accompanied by a loss in tensile strength, and if this should develop as a fact from further experiments, the conclusion to be drawn would be that the observed increase in transverse strength is not due, as supposed, to a relief of internal strains, but rather to their intensification.

It is well known that cast iron exhibits a transverse strength far in excess of anything to be expected from its tensile strength, and a careful study of this anomaly has revealed the dangerous internal strains as largely responsible for the result. The process of rumbling would naturably be expected to pein the surface of the metal already under cooling strain, and thereby intensify that strain, so that when tested transversely a higher result should not have been regarded as surprising. On the other hand, it is not so evident why bars beaten only on the ends should exhibit the same phenomenon, and the question arises whether the increase in the strength observed by Mr. Outerbridge is a real gain worth cultivating, or one to be had only at the expense of additional strains which it has hitherto been thought desirable to avoid. However, he does not contend that there is any real gain in strength, but only a gain resulting from release of strain, the strength of the free metal remaining unaltered, and in the case last mentioned of bars beaten only on end, it is difficult to imagine any other result than a release of strain from shock. If this should be found to be the case, another difficulty would appear in reconciling it with the fact that a higher transverse strength is also recorded for the same treatment. It would then be necessary to account for an increase in transverse strength by a release of the interal strains upon which it has been shown to depend,* and this could only be done on the assumption of internal strains in excess of those produced in bending, causing the test bar to break within itself before the tension side is ruptured. This may be a difficult point to verify or dispute, but it is a natural deduction from Mr. Outerbridge's experiments, and the only way in which it seems possible to reconcile his facts with his theory.

It is quite easy to believe that initial strains in cast iron may be released by shock, and quite easy also to admit that they may be increased in the rumbling barrel by peining, but an increase in transverse strength no doubt results, and the cause remains to be demonstrated. If the theory advanced by Mr. Outerbridge is correct, the forces developed transversely take on a new aspect in the strain diagram, tending to show that a certain amount of annealing will add to the strength, while a further amount will detract. It is pretty well settled that the metal in test bars when freed from strain has everywhere about the same strength, and it may now appear that while some initial strain adds materially to the transverse strength in the ordinary process of cooling, this strain is generally excessive, and can be relieved to advantage by shock.

Mr. Outerbridge is certainly to be congratulated on the work he has accomplished, and any further researches he may make will be looked for with a great deal of interest. WILFRED LEWIS.

To THE EDITOR:

I have read with pleasure Mr. Wilfred Lewis's interesting inquiry regarding the possible effect of vibration upon the tensile strength of cast iron, also his views respecting the novel theory of "the mobility of molecules of cast iron" advanced in my communication read before the Institute of Mining Engineers and published in your last issue.

The first query affords me an opportunity to now point out a radical difference of physical or molecular condition of cast-iron bars prepared for "tensile" and for "transverse" tests, with which subject I deemed it unwise, for reasons hereinafter explained, to confuse the main issue in the original paper.

I believe it is generally admitted by engineers, that, in order to obtain reliable tensile tests of cast-iron bars, it is absolutely necessary to turn the pieces in a lathe (or otherwise machine them), because rough bars are always somewhat crooked and irregular in size and shape; therefore, no matter what kind of "adjustable grips" are used, a rough cast-iron bar, when pulled, will be subject to "bending" or "torsional" stresses, rendering the records unreliable. Such pieces, in fact, often break within the jaws of the grips.

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* It has been shown by Prof. J. B. Johnson, in his admirable paper on the strength of cast iron, that its wonderful transverse strength may be largely explained by a study of its strain diagrams for tension and compression; but that this is not enough to account for its full strength, the cooling strains being also required to complete the explanation.

I have records of several such tensile tests of rough bars that were subjected to repeated shocks or vibrations, and companion bars not so treated, but I do not consider them worthy of a place in my original paper, which aimed to present uncontrovertible facts only and to offer a rational hypothesis in explanation thereof.

I stated: "In conclusion, it should, perhaps, be observed, to avoid the possibility of misunderstanding, that the molecular annealing of cold cast iron by successive slight shocks differs from annealing by heat, in that it has no power to change the condition of carbon in the casting, or to alter the chemical constitution in any way. All that is claimed is, that every iron casting, when first made, is under a condition of strain due to difference in the rate of the cooling of the metal near the surface, as compared with that nearer the centre, and also to difference of section; and further, that it is practicable to relieve these strains by repeatedly tapping the casting, thus permitting the individual metallic particles to rearrange themselves, and assume a new condition of molecular equilibrium."

When the surface metal of a cast-iron test bar is turned off in a lathe the strain or tension, caused by the difference in the rate of cooling of the metal near the surface, as compared with that nearer the centre, is at once relieved, and thus there could be no difference, if my hypothesis is correct, in tensile strength of such bars due to any mechanical treatment, by shock or vibrations, either before or after turning the piece in the lathe.

The majority of castings—such as hammer frames, housings for rolls, columns, etc., etc.—are not turned or planed off on their surfaces (except in a few places to make close-fitting joints or wearing surfaces), and are thus when put into use subject to the same condition of strain as that existing in transverse test bars; *the quantitative measure of such strains* in such test bars being the pith of the new investigations revealed in my communication entitled "The Mobility of Molecules of Cast Iron."

With respect to the second query of Mr. Lewis, I am glad that I said before he asked it: "A statement so surprising should not be made without sufficient data to establish its correctness beyond cavil, since it is contrary to former belief, certain to be questioned, and properly so." What has happened since this publication?

The paper was read in February at Pittsburg, and first printed in *Engineering News*, February 27th, 1896, nearly four months ago.

All of the practical metallurgists who were present at the meeting stated that it was their intention to repeat the experiments immediately on their return to their foundries. The discovery of molecular annealing of cold cast iron has called forth and is continuing to elicit many expressions of surprise from practical men and theorists everywhere, and has received flattering and unexpected generous public notice, both by re-publication and by editorials, in a score or more of prominent technical publications, both in this country and in Europe.

I have also been the recipient of letters from large manufacturing establishments, enclosing, in some instances, records of similar independent tests made by them, *exceeding the maximum gains stated in my paper.* One of the latest of these letters gives a gain of 820 pounds transverse strength of a cast-iron test bar 1″ section 12″ long, which had been tossed in a tumbling barrel for 2½ hours, as compared with a companion bar cast in the same mold from the same runner, not so treated; this gain was equivatent to 25.9 per cent.

Records from another establishment show gains of more than 30 per cent. in molecularly annealed bars.

The largest gain in tranverse strength mentioned in my paper was a little less than 19 per cent. In addition to these tests some interesting practical recent applications of the discovery of the principle of molecular annealing have been brought to my attention by others.

It has, moreover, been pointed out to me by an observant workman, that when old castings of irregular dimensions (such as pulleys) are broken, there is an entire absence of the "jerk" and springing apart of the rim, or other light part of the casting, characteristic—to a greater or less extent—of all new pulleys, or similar castings (even when made from softest iron) if broken soon after being cast. This corroborates the claim made in my paper that "old castings are more reliable that new ones, unless they have been misused."

Apologizing for the length of this informal note, I hope that

I have clearly indicated the difference of conditions existing in cast-iron bars which have been molecularly annealed, when turned or machined for tensile tests, and similar bars tested in "the rough" for transverse strength. This difference does not refer in any way to the supposed fact that the "skin" of a casting is harder—and therefore stronger—than the centre.

A. E. OUTERBRIDGE, JR.

In further corroboration of Mr. Outerbridge's claim that old castings are better than new, Sir Frederick Bramwell (in "Construction of Artillery," Inst. C. E., 1860) says:

"A gun kept for six years endured 800 discharges before it burst, while another gun, cast at the same time, made of weaker material, but kept as long before testing it, endured 2,582 discharges and did not burst.

"Guns of the same description tried thirty days after casting burst, one at the 84th and the other at the 72d discharge.

"This result showed that it was not impossible that the superior manner in which guns cast some years ago, but recently used, had stood their work as compared with those of modern use, was not due, as was commonly supposed, to the better quality of metal used in those days, as compared with the present, but to their having been cast a long time, and to the strains that existed in them from unequal contraction when originally cast having ceased, while the strains in the new were still exerting a prejudicial effect."—EDITOR.

U. S. NAVY YARD HOSE SPECIFICATIONS.

1. The hose is to be rubber-lined cotton, woven or knitted (or both combined) fabric, multiple or jacketed seamless, with couplings complete.

The internal diameter is to be two and one-half (2½) inches. Length measured over all is to be not less than fifty (50) nor more than fifty-two (52) feet.

Measurement to be taken after submitting the hose to one hundred (100) pounds water pressure to straighten it and then relieving it of all pressure.

Weight per section with couplings shall not be less than fifty-two (52) nor more than sixty (60) pounds.

2. The lining is to be of fine Pará rubber, not less than three (3) calendered, in one solid body, not less than one-sixteenth (1-16) inch in thickness, exclusive of cement or other backing.

The tube before insertion is to be smooth and well made ; it is to be of uniform thickness and quality throughout its length, and is to have a well made lap.

The rubber is to show upon analysis between forty-five (45) per cent. and fifty-five (55) per cent. of ash, the balance to consist only of sulphur and fine Pará rubber.

Only such freedom from corrugation in lining is to be required as can be procured by the best methods of lining, which are to be employed, viz. : By the proper insertion into a good woven or knitted fabric or both combined, of a rubber tube of the required thickness, smoothed before insertion, properly cemented for adhesion with the best quality of cement for the purpose, and such degree of vulcanization as will produce best and most durable results.

3. Cotton cover is to be of best quality Gulf or Peeler cotton, well and evenly and firmly woven or knitted, or both combined, into a multiple or jacketed seamless fabric, to be free from unsightly or injurious defects, or defects of any kind except such trifling ones as are incident to the best practical manufacturing.

4. Each length to be fitted with the Navy Standard Couplings, eight (8) threads to the inch, which shall be made of composition consisting of nine (9) parts of copper to one (1) of tin, to be smooth finished with full sized waterways and the couplings on each length shall not exceed five (5) pounds in weight. A margin of a quarter (¼) of a pound being allowed. Each length of hose to be furnished with a galvanized wrought steel spanner.

5. The maker's name, with the year and month of manufacture, and the grade or quality, to be stenciled in two (2) places on each length of hose, the marks being four (4) feet from the couplings. The marks to be red and the letters one (1) inch high.

The couplings to be stamped with the same information in letters one-quarter (¼) of an inch high.

6. Tests:

I. The hose to be stretched out horizontally and on a clean surface for inspection, connected with the pump and filled with water, leaving the air-cock open, allowing the air to escape, after which the air-cock is to be closed and a pressure of one hundred (100) pounds per square inch is to be applied, the air-cock is then to be opened, and when the gauge shows zero, the test is to be begun by taking original measurements.

II. Each length, with couplings attached, to be subject to a pressure test of two hundred and fifty (250) pounds to the square inch to expose imperfections, and insure proper attachment of the couplings.

III. From each delivery of ten (10) lengths one section will be selected by the Board of Inspection, and be further subjected to a test of four hundred (400) pounds to the square inch. For deliveries of less than five (5) lengths, the Board of Inspection may waive this test if satisfied that the hose is of a quality desired.

IV. The hose, while under test laid in II and III, shall not leak, sweat, nor break the threads of the cotton cover; it shall not contract in length or diameter; it shall not increase its external diameter more than one-eighth (⅛) inch at any point. The limit of elongation for each length shall be forty-five (45) inches under II, and fifty-five (55) under III, and in both instances, each length must run out nearly straight under pressure without turning more than two (2) turns, and must not rise from the floor nor writhe.

V. Each length must coil within a circle whose diameter does not exceed thirty (30) inches.

VI. A piece of rubber cut lengthwise of the lining one-half (½) inch wide, and four (4) inches between the jaws, must stretch to four (4) times its own length (with a variability of four (4) inches more or two (2) inches less) with a pull of ten (10) pounds, and it must be capable of stretching to six (6) times its own length (with an increased pull) without breaking; and when released the rubber must return in one (1) minute to within one-half (½) inch of its original length of four (4) inches.

Test pieces may be cut from any part of the length of the hose the inspector may choose, and if the test is satisfactory, that particular length will be accepted by the government.

7. All fabrics to be antiseptically treated, a written guarantee must be given to that effect by the manufacturer.

8. If at any time during a period of two (2) years from the date of delivery of a lot of hose, a section, or sections of it, burst or show signs of weakness which is evidently due to defects of manufacture, and not at all incident to the customary wear and tear of use, such quantity of defective hose shall be replaced by new hose by the contractor without further cost to the government.

The defective hose shall be sent to the navy yard nearest the place of its purchase and the contractor from whom it was bought shall have ample opportunity to inspect and test the defective portions before replacing them by new hose.

9. The successful bidder shall be notified when and where the tests are to be made, and will be permitted to be represented as a spectator when said tests are made.

In case he objects to the results of the tests, he may ask for expert examination, in which case the government, if it deems his request well founded, shall appoint an expert, the contractor one expert, and in case the two cannot agree in a finding they shall appoint a third; and the result of said expert examination shall be binding and final.

The expense of said expert examination shall be borne by the loser.

PENCOYD 18-INCH BEAMS.

The Pencoyd Iron Works, of Pencoyd, Philadelphia, Pa., have put on the market an 18-inch beam of which the following are the elements:

	Elements of 18-Inch I-Beams.		Pencoyd Iron Works.	
1	Size in inches,		18	18
2	Section number,		528	527
3	Area in square inches,		19.7	16.2
4	Weight in pounds per foot,		67.0	55.0
5	Moments of inertia.	Horizontal axis,	973.5	809.0
6		Vertical axis,	30.29	20.82
7	Square of the radius of gyration.	Horizontal axis,	49.42	49.94
8		Vertical axis,	1.54	1.28
9	Radius of gyration.	Horizontal axis,	7.03	7.07
10		Vertical axis,	1.24	1.13
11	Resistance,		108.2	89.9
12	Add to resistance for each additional pound per foot,		0.88	0.88
13	Co-efficient in net tons for greatest safe load dist'd, 16,000 pounds fibre stress,		576.9	479.4
14	Add to previous co-efficient for each additional pound per foot,		4.7	4.7
15	Co-efficient for deflection.	Distributed load.	0.00000161	0.00000193
16		Centre load.	0.00000264	0.00000317
17	Maximum load in net tons,		48.8	32.8

NOTES AND COMMENTS.

THE tests of the strength of wire glass plate of a thickness of 1.2 c. m. which have heretofore, in 1892, been made by Dr. Hartig (cf. *Civilingenieur*, 1892, p. 265), have now been completed by conclusive tests of Siemens' wire glass in plates of 1.5, 2.0, 2.5, and 3.0 c. m. thickness, which have recently been repeated in the laboratory of the Technical High School at Dresden. The results obtained confirm those which the former series of experiments had demonstrated, viz.:

That the specific breaking-strain of the wire glass surpasses that of the wireless glass, made under the same conditions, by more that 40 per cent., while, at the same time, the characteristic and practically valuable property of the wire glass, that it retains its broken fragments, is not here taken into consideration.

We here reproduce a compendious statement of the results of these experiments, as a reliable basis for such calculations as may become requisite, especially by building inspectors, and refer in addition to the fully detailed data published in the *Civilingenieur*.

The experiments were carried out with cast flint-glass without wire inlays, and with wire glass of the same material made and annealed under similar conditions.

Denoting the width by *b* c. m., the space between the supports by *l* c. m., and the thickness of the plate by *h* c. m., the results of a concentrated load in the middle of the supported space, at the moment of fracture, in 24 tests, give the following empirical formulæ:

For the breaking load of the wire glass: $\text{Pkg.} = \dfrac{265\ \text{b}\ \text{h}^2}{1.68\ \text{l} + \text{h.}}$

For the wire glass: $\text{Pkg.} = \dfrac{22.5\ \text{b}\ \text{h}^2}{0.0792\ \text{l} + \text{h}}$,

Assuming, for instance, $\text{b} = 50$ c. m, $\text{l} = 50$ c. m, and $\text{h} = 1$ c. m, we obtain for the breaking load:

For the wireless glass: $\text{P} = 156$ Kg.
For the wire glass: $\text{P} = 227$ Kg.

The individual tests varied from the calculated values for the breaking load P, to such an extent, either way, that the probable error of several observations may be stated to reach 25 per cent. of the calculated value. If, therefore, it is desired to be within safe limits, it will be well to assume a five-fold security—that is, to confine the permissible load to a fifth of that calculated.

For equally distributed load (*e. g.*, snow), the values of P are to be doubled.

Assuming, for instance, $b = 50$ c. m., $l = 50$ c. m., and $h = 1$ c. m., we obtain as a permissible load to be concentrated in the middle, with five-fold safety:

$$\text{For wireless glass; } 5\ P = \frac{265\ b\ h^2}{168\ l + h} = 156 \text{ Kg to } 32 \text{ Kg.}$$

$$\text{And for the wire glass: } 5\ P = \frac{22.5\ b\ h^2}{0.0792\ l + h.} = 227 \text{ Kg to } 45.4 \text{ Kg}$$

For equally distributed loads these values would be doubled, and there would result a permissible loading with five-fold safety:

For wireless glass to 64 Kg.
And for the wire glass to 90.8 Kg.

If the thickness of a glass plate is to be calculated from the formulæ given for the breaking strain, the solution of the quadratic equation for h is applicable in individual cases for the required plate thickness h.

For instance, if $P = 500$ Kg, $b = 50$ c. m., and $l = 50$ c. m., the thickness *h* is determined:

For wire glass at l. 57 c. m., with the load concentrated in the middle of the narrowest space between the supports. Such a plate would accordingly bear a load of 100 Kg with five-fold safety.

Further experimental tests of directly loaded, horizontally laid wire glass have demonstrated that a wire glass plate, supported on all four sides will, on an average, resist a breaking strain 1.3 times greater than a plate supported on but two sides. It is, however, recommended to leave out of consideration the possible increase of the breaking strain admissible in cases of glass supported on all sides, and rather to allot this factor to the side of safety, more particularly inasmuch as strains due to jar and vibration are to be considered, as for instance, in floor lights, coverings of balconies, etc. There accordingly remains for the wire glass, supported on all four sides, the following formula as being approved for the assumable breaking strain of the narrowest supported spaces under a concentrated load:

$$P\ \text{Kg} = \frac{22.5\ b\ h^2}{0.0792\ l + h}.$$

NATIONAL CONVENTION OF FOUNDRYMEN AT PHILADELPHIA.

Over two hundred foundrymen and representatives from all parts of the country met on May 12th, 13th, and 14th, to consider the establishment of a permanent organization, to be known as the American Foundrymen's Association. Judging from the interest shown by the very large attendance, nothing short of success may be expected. The benefits to be derived from such an organization are numerous. Those directly interested in foundry work will appreciate it the more because of its motto, "the advancement of all things pertaining to foundry practice."

F. Schumann, of Tacony Iron and Metal Works, presided. In his opening address he said: "We have undertaken to bring together here those interested in the welfare of an industry consisting of nearly 4,000 separate establishments, with an aggregate capital invested of about $115,000,000, employing about 120,000 persons, whose annual wages amount to nearly $63,000,000. Some 2,600,000 tons of castings are produced annually, requiring some 430,000 tons of coal and coke. The total annual disbursements for material and labor amount to $114,000,000. This is the first time that those engaged in so great an industry have ever met to confer upon questions relating to their mutual welfare."

During the convention papers were read by the following well-known authorities:

Charles James, M. E., on "Chemistry of Iron with Determinations."

D. J. Matlack, of I. P. Morris Co., Philadelphia, on "Apprenticeships, Their Value and How to Make Good Molders."

Thos. D. West, of Sharpsville, Pa., on "Utility and Advancement of Green and Dry Sand and Loam Molding."

W. J. Keep, of Detroit, on "Physical Tests and Chemistry of Cast-Iron."

Samuel Groves, on "Gear Molding and Gear Molding Machines."

P. H. Mumford, on "Molding Machines and Their Applications."

The sessions were held in the hall of Franklin Institute.

The visitors and their friends were lunched on Wednesday at the restaurant of Builders' Exchange, and given a reception and banquet at the Academy of Fine Arts, by the Foundrymen's Association of Philadelphia.

The Mechanical Engineer's Pocket-Book, a reference book of rules, tables, data, and formulæ, for the use of engineers, mechanics, and students. By William Kent, A. M., M. E.; John Wiley & Sons, New York. Morocco, flap, 4¼x6¾ ins.; pp. 1,100. Price, $5.

This pocket-book is the result of twenty years' collection of data by the author, including four years putting the matter into shape for publication. It fills the same field in mechanical engineering that Trautwine's book does in civil engineering. The work is arranged in logical order, and is provided with both a very complete table of contents and an alphabetical index. References to authorities, with date and page, are given throughout the book, and a list of authorities which are thus referred to contains over five hundred names. The principal headings of chapters are Mathematics, Materials, Strength of Materials, Mechanics, Heat, Air, Water, Fuel, Steam, Gas, Locomotives, Shafting, Pulleys, Belting, Gearing, Hoisting Friction and Lubrication, the Foundry, the Machine-shop, Refrigerating Machines, Marine Engineering, Electrical Engineering.

About one hundred pages are devoted to the subjects of testing and strength of materials. An extraordinary amount of matter is condensed into this space, including an abstract of Kirkaldy's results, various formulæ and tables for strength of columns and other shapes, etc. This portion of the work forms a treatise in itself on Strength of Materials, and as such we cordially commend it to our readers.

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Glucinium and its Uses.—Prof. W. H. Morse, of Garwood's, is engaged in developing the manufacture and use of the rare metal glucinium. He has demonstrated that it is considerably lighter than aluminum, more durable and less extensible than iron, and with an electric conductivity greater than that of copper. Glucinium is now worth about $18 a pound. As this is only one-tenth the price of platinum, and as it is substitutive for it, the professor's experiments are directed toward obtaining a ready production, and placing it in quantity for electrical work.

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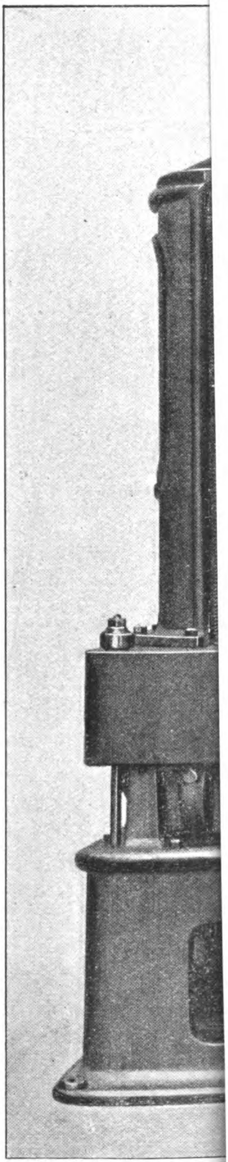

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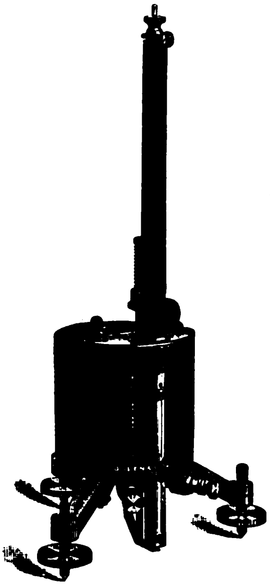

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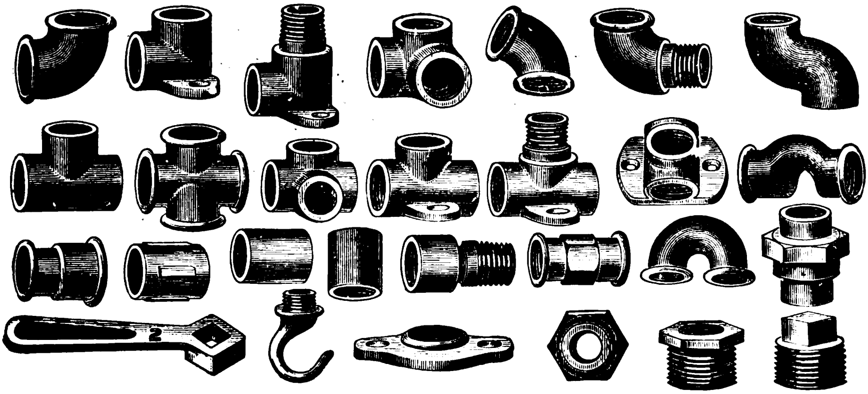

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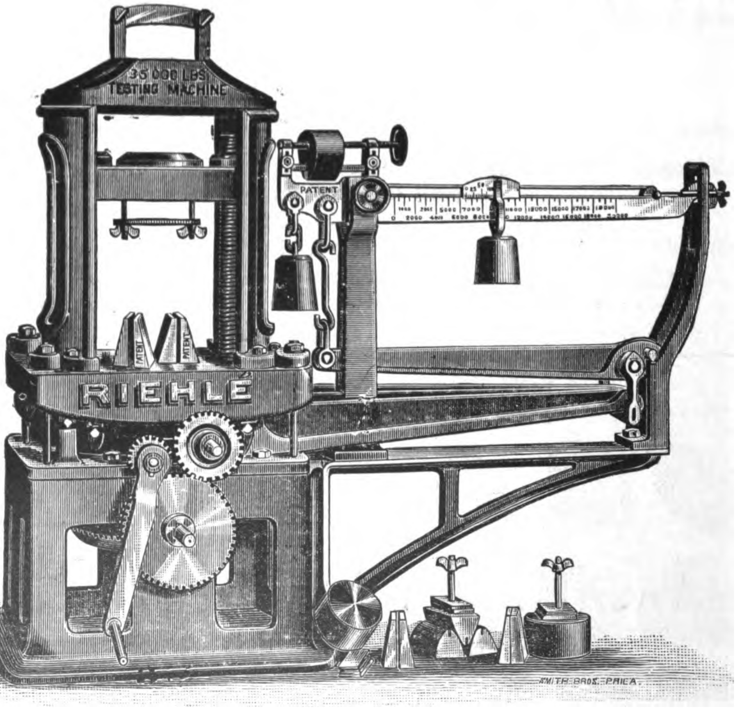

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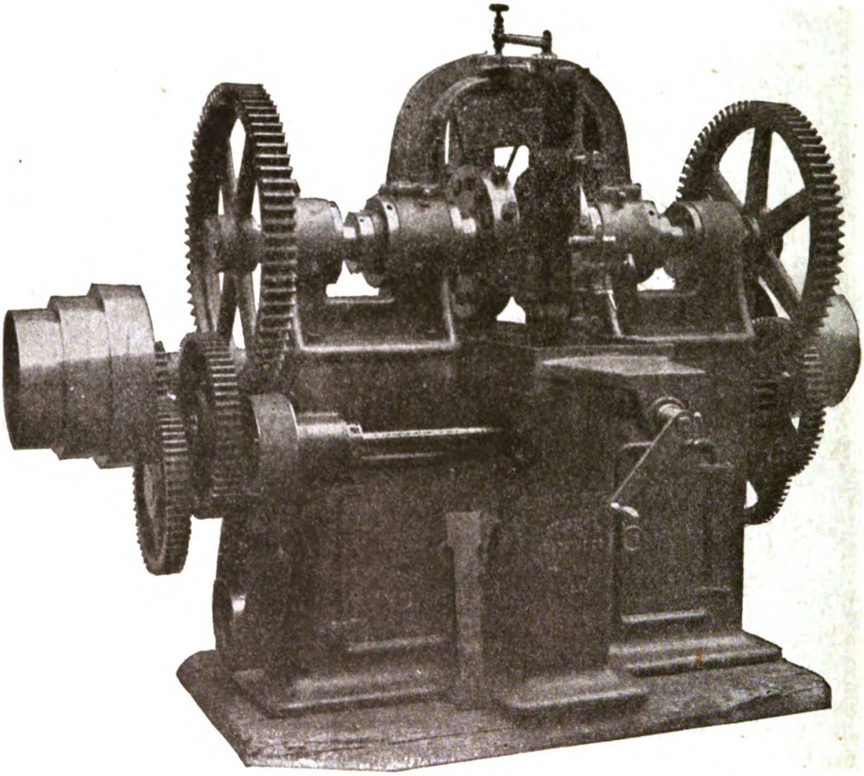

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Vol. I. OCTOBER, 1896. No. 4.

The Digest
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Physical Tests
AND
Laboratory Practice.

A résumé of Practical Tests made in the Laboratories of the World.

JOSEPH W. BRAMWELL, EDITOR.

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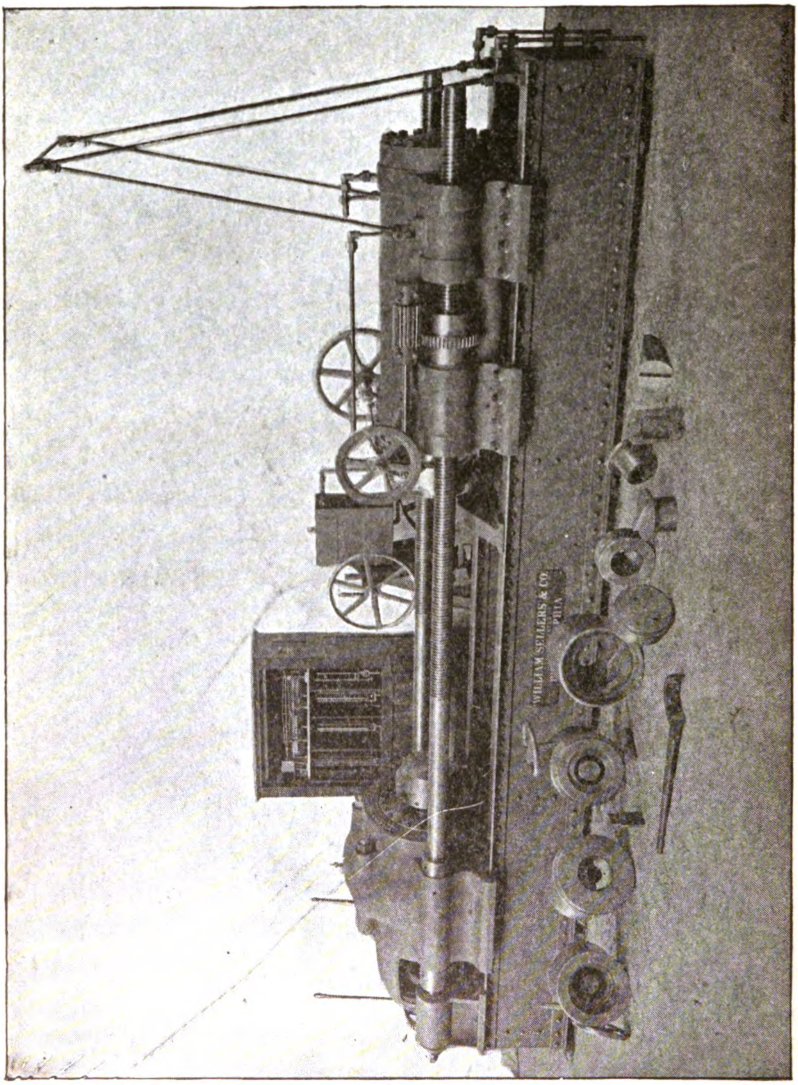

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A RÉSUMÉ OF PRACTICAL TESTS MADE IN THE LABORATORIES OF THE WORLD.

Vol. I. OCTOBER, 1896. No. 4.

PROFESSOR L. v. TETMAJER,

President of the Congress and International Society for Testing of Building Material.

PROFESSOR L. v. TETMAJER, whose photograph is here reproduced from the September number, 1895, of the *Schweiz. Bauzeitung*, was born in Krompach, Comitat Zips, in Upper Hungary, 1850. His father was director of the Krompach-Hernäder Iron Works. The father, perceiving the fondness and keen interest shown by his son in the study of iron and its productions, gave him, by the means he had, good opportunity to cultivate his talent for experimenting. Young Tetmajer, when only fifteen years old, was very skillful in chemical and physical experiments. In 1861 he entered the gymnasium at Rosenau, and in 1862 the high school at Kaschau, in Upper Hungary. At seventeen years of age he passed his examination there and entered the Polytechnikum in Zürich, which at that time claimed such noted professors as Zeuner, the inventor of the link motion diagram, who now lives in Dresden; Culman, who in 1866 laid the foundation for the science of graphic statics; Semper, the well-known architect; Scherr, the republican-minded, free-thinking German writer of literature; Kenkel, who, after his stormy life—had been sentenced to imprisonment for life for participation in an uprising, but had been pardoned, partly through the influence of his wife—now Professor in Archæology and Art History; Kundt, the successor to the well-known Clausius.

At this place many of the great men from foreign countries had gathered, and because of their free ideas and manner of expressing them were not able to find occupation in their own country.

In 1872 young Tetmajer graduated from the Civil Engineer's Department, at the head of which was what he called the "God-favored triumvirate," Culman, Pestalozzi, and Wild. Culman was Professor in Bridge-building and Graphic Statics; Pestalozzi—a grandchild of the popular speaker—was Professor in Road-building and Hydraulics, and, in conjunction with Culman, in Railroad Construction. The lately deceased Wild, the great topograph of Switzerland, was Professor of Surveying.

In the beginning of 1872, Tetmajer entered in the employ of the Swiss Northeast Railroad Company, where he was engaged as bridge constructor. In 1873 he received from Culman the flattering offer of a position as his first assistant, in which capacity he remained until Culman's death in 1881.

Meanwhile he had entered the Austrian Army service (1875–1876), but after his resignation as officer he returned to Zürich, where he, in 1878, was elected Honorable, and in 1880 as Extraordinary, Professor. He was offered the Professorship of Architectural Mechanics and the charge of the recently established bureau for testing of building material.

To these duties was added the instruction in bridge-building, but he soon resigned these to become instructor in the technology of building material, iron metallurgy, and structural iron work.

After the death of Professor Bauschinger, in 1893, a position was vacant not easy to fill. Professor Tetmajer, however, was elected to carry on the late Professor's work, but he reluctantly declined. Due to the above vacancy, Professor Tetmajer had his position at Zürich greatly improved.

Professor v. Tetmajer's greatest researches are closely connected with the Bureau for Testing Building Materials at the Polytechnikum at Zürich. The results of his many works are laid down in the *Mittheilungen* issued by this Bureau.

Of these, seven books have now been published (1884–1894).

The introduction to the first part gives a past history of the Bureau, while the fifth book describes the present arrangements. The other books treat, as before mentioned, of the researches carried on by the Bureau, these researches having for an end to place Switzerland in a position where it would be independent of other countries, at least in certain branches of its industries, and to solve scientific problems. Some of the data has already been published in Swiss papers, particularly the *Schweizeriche Bauzeitung* and the *Schweizeriche Eisenbahn.*

The first book (1884) contains the "Methods and results in testing natural and artificial building stone," and treats of a number of tests, according to which Tetmajer classifies the Swiss building stone in several groups, depending on quality. For rock and volithic limestone he makes use of the "Tetmajer's coefficient" for classification, this coefficient being the ratio between the strength of the material saturated with water and that in a dry state.

Further, it is an expression of the porosity of the material or of its capacity to absorb water, and thereby indicates the amount of solid matter contained in a unit volume, and is a measure of the ability of the material to withstand freezing.

These rock species he divides into three classes, with the coefficients at least 0.75–0.6 and 0.5, while for limestone he reduces it to two, where the first class has a coefficient of at least 0.75, and the second at least 0.6. For the artificial stones[1] he has devised a classification, also depending on the same coefficient, and considers brick to be of first quality when the coefficient is over 0.9; divides these again, depending on the manner of production, and for ordinary hand-made brick of the first quality he requires a compressive strength of at least 200 kg. pr. □ cm. He has also contributed to the literature on building stone, for its preservation,[2] its resistance to climatic changes,[3] and the mode of testing the material to ascertain this data.

The second book treats on "The methods and results from tests on the Swiss wood for building purposes."

These and the previous researches were made to exhibit at the Swiss Exposition in 1883, and most of the results have already been printed in the official catalogue of the Exposition under group 18.[4]

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[1] A short extract of the literature relating to artificial stones, particularly the action of lime in mortar is given in *Deutsche Ziegler und Jöpfer Zeitung*, 1884, p. 71.

[2] *Schweiz. Bauzeitung*, 1887, Vol. IX, p. 91. Special experiments have been made in the Bureau with Kesster's fluorites for preserving sandstone f. ex.Luzern sandstone from the Lion monument.

[3] Communication in June, 1895, from Tetmajer and Prof. Grubeumann to the special committee.

[4] See also: Meister, Locher, Roch and Tetmajer's work on *The Swiss Building Materials at the Exposition, 1883*. Fourth edition Zürich, 1884.

Before experimenting on the Swiss timber it was necessary to make certain rules, the making of which Tetmajer considered partly the demands of the trade, and partly the influence the experiments might have on the timber industry if the strength of the material was ascertained at different points of the tree, and also the connection between the strength, the climatic, and geological conditions.

To ascertain the latter it was agreed that records should be made of location of tree whether growing South or North, if the location was more or less than 1,300 metres above the sea level, and whether the ground was mixed with sandstone, limestone, slate or granite. The tree should be felled in December, and the test pieces should be cut at a distance from the ground equal to half the height of the tree.

Minute directions were given about the dimensions and location of these test pieces. Special care was taken in the experiments for transverse strain, partly due to the importance this has in practice, and partly because the coefficients obtained in this way are larger and easier to determine accurately than those obtained by any other method.

With these results as a basis, he determined the quality of the specimens, and ranged their relative value according to their transverse strength,[1] inasmuch as the wood, to have a great transverse strength must combine great tensile strength with elasticity. During his experiments on resistance to compression he found that for a column between movable supports, the formulæ given by Euler coincided with the one given by Bauschinger for iron rods, all other conditions being equal, and also that the coefficient η, by Tetmajer designated with η in Rankine's formula is not a constant,[2] but varies with the variable relation between the diameter and length of the column. At later experiments he made up a formula for this variation.[3]

As main results of those in the second book of described experiments he found that white spruce should be selected that had grown at a less elevation than 1,300 metres, preferably on hillsides facing north, and also that the timber used for the most important work should be cut from the forests grown under these conditions, while red spruce grown in the zone above 1,300 metres was to be preferred over those grown at less elevation, and this species could also be grown on ground facing south with less loss of strength than the white pine.

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[1] He also did the same for cast iron in his later mentioned work on *Baumechanik*, second vol., first half, against which Bach demonstrates in *Zeitschrift des Ver. d. Eng.*, 1889, p. 453.

[2] See *Engenieur*, 1892, p. 45.

[3] "The Strength of Timber," in *Schweiz. Bauzeitung*, 1888, Vol. XI, p. 110 (reprinted in *Dingler's Polyt. Journal*, Vol. CCLXX, p. 357). See also his *Baumechanik*, second part, first half, 1889. From a note in *Annales des Ponts et Chaussées*, 1894, Vol. II, p. 280, it would seem that Tetmajer may have made later experiments.

Space forbids me to enter any farther upon these results, which would seem to be of great economical value for a rational forestry-system.

In the third volume (1886) he published the methods and results in testing of iron, steel, and other metals. This volume throws further light on the first part of the treatise, *A Rational Nomenclature and Classification of Material for Building Construction,*[1] published by the Society of Swiss Engineers and Architects in 1883.

For metals, as for wood, Tetmajer designates its usefulness by a number that is proportioned to the capacity of the material, and for this number selects $C=\beta\times\lambda$ where β=tensile strength in tons per □ cm., and λ=the coefficient of elasticity.

There is hardly any doubt but that Tetmajer's "quality number"[2] is a superior way to designate the grade of a metal than that given by Wöhler (the sum of the tensile and compressive strengths); but, although his theory has many followers, it has also many enemies,[3] and has not received universal acknowledgment. For example, it is well known that Swedish iron is superior to others for art purposes, but its "quality number" need not on that account be very high, as its strength may be inferior, which for this purpose is not necessary.

Of course Tetmajer perfectly well understands that forging and bending tests, etc., would be a more accurate way to determine whether the Swedish iron is more suitable for this use than the quality number, but he holds that with no other simple number can the sum of its most important technical qualities be designated.

For the experiments on which these numbers are based I must refer the reader to the volume itself. I will point out, however, that in plotting the curves Tetmajer gets symmetrical hyperbolas confining the areas, inside of which the single points representing the quality of the material are located, and at a recent experiment with material from a bronze gun he demonstrated his methods superior to those of Wöhler's.

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[1] The second part deals with hydraulic cements.

[2] See *Schweiz. Eisenbahn.* 1881, Vol. XV, p. 92, and 1882, Vol. XVI, p. 109; also, *Schweiz. Bauzeitung,* 1883, Vol. I, p. 35, where the later related trials with material from the bronze gun are treated on; also, *Stahl und Eisen,* 1881, pp. 100 and 190, and same paper, 1882, p. 365.

[3] See *Zeitschr. des Ver. d. Eng.*, 1889, p. 453.

This volume contains, furthermore, experiments on the strength of wire rope[1] and its deterioration from bending, and also the most important experiments on the value of Thomas iron as material for construction.[2] These were tests on a number of German standard wrought iron sections from "Gebrüder Stumm's" iron works in Neukirchen at Laarbrücken in 1884.[3]

The results from these tests show that Thomas iron is, under certain conditions, as good as wrought iron, and that small amounts of impurities are no more dangerous with the former than with the latter; that wrought iron after being punched is brittle at the edge around the hole, but that the brittleness disappears with annealing or after the hole is reamed to a diameter $1^{m}/_{m}$ larger than the punch; and finally he designates the Thomas iron manufactured by Stumms as being well adapted for bridge building together with wrought iron.

The third volume also contains the results of experiments on the cables in the suspension bridge at Freiberg, tests on rivets and plates used for shipbuilding, etc., and a number of experiments on the influence of punching on wrought iron.[4] He found that the strength of the material was lessened near the edge, but it was only necessary to ream the hole 1 or 2 $^{m}/_{m}$ larger than the diameter of the punch, to remove the compressed metal and restore the material to its original strength, and also that it was entirely unnecessary to ream bored or drilled holes to increase the strength as this was already done by the operation of boring.

This volume also contains tests on the strength of riveted joints;[5]

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[1] On Tetmajer's experiments with wire rope see also *Schweiz. Eisenbahn*, 1881, Vol. XV, pp. 5 and 6, and the fourth volume of the communications, and for hemp rope see *Schweiz. Eisenbahn*, 1881, Vol. XV, p. 4.

[2] In these experiments Tetmajer found the modulus of elasticity as determined by transverse testing to be much less than when determined by tensile trials. See *Zeitscher. des Ver. d. Eng.*, 1888, p. 223, and Bach's *Clasticitäi und Festungkeit*, 1894, p. 109.

[3] These trials were published separately in Zürich, 1885, and are reprinted in *Dingler's Polytechnic Journal*, Vol. CCLXI, p. 427.

[4] The experiments with wrought iron are exhaustively treated in *Schweiz. Bauzeitung*, 1886, Vol. VII, p. 33. From there reprinted in *Stahl und Eisen*, 1886, p. 173, and *Dingler's Polyt. Journal*, Vol. CCLXI, p. 427.

[5] For his formulas for this see his work on *Baumechanik*.

some trials on the strenghth of iron and steel, especially steel rails; also chemical analysis of cast-steel rails with accompanying coefficients for strength; a treatise on the inspection of rails and the manner in which this inspection should be conducted, and finally some trials with copper and bronze. The fourth volume (1890), issued from the Swiss Test Bureau, deals with the "Methods and results of tests to determine the strength of iron and other metals," and bears testimony that wherever Professor Tetmajer had an opportunity for more extended experiments he endeavored to carry out such as would give the whole work a more finished character, and would dispose of such questions as the coefficients for use in iron construction, etc. From this volume, as from all the others, it can be plainly seen to what a great degree the Bureau had the support of the private industries.

Between the publication of the third and fourth volumes the "Festigkeitskongresser" took place, and immediately after the publication of the rules[1] regulating the delivery of steel and iron, by which the "derein deutscher Eisenhüttenleute" tried to settle the relation between consumer and producer. At this time (in 1890) the value of the Bureau was so apparent that the Swiss government consented to furnish the means for a new building, about which the fourth volume contains information.

The fourth volume, besides the above mentioned matter, contains a great many tests on material from Wendel & Co.'s iron works in Hayauge. Here, for the first time at the compression tests, Tetmajer treats separately of the modulus of elasticity, the beginning of deformation and limit of elasticity, above which the material receives a permanent "set," which latter limit could not be observed with Bauschinger's reflector. This had to be determined with one. of Tetmajer's invented apparatus. This machine could not always register the sudden changes that sometimes occur at this limit, but wherever it could be determined it was considered as the compressive strength of the test specimen. He also gives here the results of tests on Bessemer steel, which show how unreasonable the Austrian edict was against the use of Bessemer steel in railroad bridges, while the use of Martin steel was allowed, and finally he gives a series of analysis and tests of different kinds of slag.

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[1] The *Engenieur*, 1893, page 230, contains this as well as later publications on this subject.

A few years earlier[1] Tetmajer had demonstrated the correctness of Bauschinger's tests of Euler's formula for the strength of iron columns between movable supports, and had found the same to be true also for wood, viz.: that the letter H in Schwarz's formula (by Tetmajer designated by η) varied with the ratio of the length L to the section of the column, or as $\frac{L}{K}$, where K is the least distance to the outer fibres of the section ($FK^2 = I$), and he had also established a formula for determining η from this ratio.

At the trials of this character with iron from Wendel & Co.'s iron works, which are described in the fourth volume, he came to still another conclusion, viz.: That the strength in tons per square centimetre (1 ton = 1,000 kg.) could be calculated from the following expression:[2]

$$\beta k = 3.207 \div 0.01157\left(\frac{L}{K}\right) \text{ for cast iron, and}$$

$$\beta k = 3.030 \div 0.013\left(\frac{L}{K}\right) \text{ for wrought iron,}$$

for all cases where $20.4 < \frac{L}{K} < 105$ for cast iron and $18.5 < \frac{L}{K} < 112.5$ for wrought iron, while for greater values of $\frac{L}{K}$ than 105 and 112.5 respectively, Euler's formula should be used, and for smaller values the strength can be calculated as for direct compression. Tetmajer had then already come to the conclusion that the strength of wrought iron columns under compression could not be designated by a simple formula, and only by varying the coefficient η could the Schwarz-Rankine formula be made useful. On this he lays particular stress, that the prevalent use of this formula is unsafe, as it should only be used in cases where $\frac{L}{K}$ is less than 105 and 112.5 respectively, and it should then be written:

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[1] See *Schweiz. Bauzeitung*, 1887, Vol. X, p. 93, reprinted in *Dingler's Polyt. Journal*, Vol. CCLXX, page 354, also *Engenieur*, 1892, p. 45.

[2] The formulas given later by Jasinsky, and described in *Engenieur*, 1895, pp. 126 and 144, are very much like Tetmajer's. The difference depends on that they are not only founded on Tetmajer's, but also on Bauschinger's and Considére's experiments. While Tetmajer's and Jasinsky's formulas are founded on the mean value of the experiments, Claxton Fiedler's formulas are based upon specially non-homogeneous materials (see Ostenfeldt's *Lectures on Technical Mechanics and Graphic Statics*, first part, 1894, p. 171), all of which is clearly explained in *Engenieur*, 1892, p. 45, and 1895, p. 143.

$$P=\frac{1}{m}\,\frac{\beta.F}{1+\eta\left(\frac{L}{K}\right)^2}$$

where m is the selected factor of safety and $\beta=2.97$ tons per square centimetre for cast iron, and $\beta=2.79$ tons per square centimetre for wrought iron.

It is also incorrect—although much in use—to make $\eta=0.0001$, when in reality the nearest approximate values for η is 0.000069 for cast iron and 0.00006 for wrought iron.

Information relative to irregular trials of the same class is given in the first half, second volume (1889, pages 167, 168) of his work on *Building Mechanics;* but in the fourth volume these formulas are corrected, as in the meantime he had discontinued the use of the Schwarz-Rankin formula.

The great many tests carried out by Tetmajer with material furnished by Wendel & Co.[1] are another proof that by the help of private persons he was enabled to conduct the tests in such manner that would give really valuable scientific results.

The other articles in Volume IV deal with tests on Zoré's iron, iron plates, riveted joints, wire rope, etc., and finally treats on the influence of the size and shape of the cross-section on tensile test-specimens. It would be out of the scope of this writing to enter upon the details of these interesting researches.

Although the next volume issued did not deal with the metals, these minerals were by no means neglected by Professor Tetmajer. In 1890 he wrote in the *Schweiz. Bauzeitung*, Vol. XVI, pp. 18, 19, about "Converter Iron as Building Material,"[2] and in 1891, in the same paper, Vol. XVII, pp. 19, 20, "About the New Inventions for Determining the Value of Wrought Iron." In 1888–91 he made extensive tests for the Aluminum Industri Aktie Co., in Neuhausen, on "The Strength of Aluminum and Aluminum Alloys."[3] In 1892 he wrote in the *Schweiz. Bauzeitung*, Vol. XIX, pp. 19, 23, about "A Contribution to the Cast Iron Question," and in 1893, in the same paper, Vol. XXI, pp. 16, 17, about "The Strength of the Middle Strut, and the value of the Material in the Mönchensteiner Bridge;"[1] and in the same year, in the same paper, Vol. XXII, p. 3, about "Thomas Iron as Material for Rivets." Regarding the latter, he comes to the conclusion that absolutely reliable rivets can be produced from Thomas iron if the latter is handled scientifically.

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[1] Described in a separately issued pamphlet in Zürich, 1890.

[2] Described in *Stahl und Eisen*, 1890, p. 1045.

[3] A short reference is made to these in *Dingler's Polyt. Journal*, Vol. CCLXXV, p. 254, and *Zeitschr. des Ver. d. Eng.*, 1889, p. 959.

In 1894 he issued a pamphlet, entitled "The behavior of Thomas steel rails under actual use,"[2] owing to a decree issued by the government the 24th of April, 1893, forbidding the use of Thomas steel on the government railroads in Hungary. A Hungarian ironworker engaged Tetmajer to appear in this matter, to induce the government to reconsider its decisions. Tetmajer collected from several countries a great deal of material bearing on this subject, with the result that the decree was reconsidered and annulled on the 6th of September, 1894.

And finally, as regards the metals, Tetmajer has given valuable reports and suggestions to the committee from the Wien Congress, amongst others his suggestion to classify the bending coefficient.

It will be seen from this that an extraordinary number of experiments in this field are due to Prof. L. v. Tetmajer, and to him is due the thanks of engineers for many practically useful formulas and coefficients.

The fifth volume dwells on the Bureau in Zürich,[3] its new building, the rules for the tests it carries out for private parties, information about the methods, the yearly report for 1892, etc., ending in a list of work done and the publications issued.

The sixth volume (1893) and the seventh (1894) treats respectively on "The methods and results in testing hydraulic cements" and "The results of special experiments on hydraulic cements." The printing of the sixth volume was commenced in 1884, but the importance of the iron tests, and later the tests on aluminum, also the change of quarters into the new building, compelled Tetmajer to postpone the tests on hydraulic cements.

The last mentioned volume first classifies the raw materials that are used in the manufacture of cements. It next contains a treatise by Prof. Dr. Heim, in Zürich, entitled, "About tungstone, its composition and its occurrence," and also a review of the "Methods for testing of raw material." Next the cements themselves are classified and defined,[1] followed by a description of the tests and the apparatus[2] used, which for the most part were designed or improved by Tetmajer. This treatise gives, as far as I can understand, a very clear and complete description for those who make themselves acquainted with the testing of hydraulic cements. In the form of tables it first gives the results of tests on chemical composition, atom-weights, time constants,[3] strength,[4] volume and cohesive power, its behavior during the process of hardening, and after each set of tables a few words explain the value of the experiments for determining the relative strength of the material. Special interest is given to the trials on slag cement, mentioned in the seventh volume, to which I will refer later.

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[1] See *Tekn. Foreningens Tidskr.*, 1891–92, p. 221, and *Engenieur*, 1893, p. 117.

[2] Reference to this is made in *Stahl und Eisen*, 1895, p. 179.

[3] This is also described by P. Debray in *L'institut fédéral suisse d'essai sur les matériaux*, Paris, 1891.

This volume is on the whole a supplement to the sixth, and contains treatises on the "value of the three-day test to determine the strength of hydraulic cements;" on the influence of the quantity of water on standard mortar 1/3; on the strength of pulverized Portland cement; on the strength of successive layers of cement; on the strength of magnesia cement; on the influence that alkali solutions have on the strength of metallic cements; the influence of water and carbonic acid on the strength of the hydraulic cements, and the influence on the same exerted by running sewerage, petroleum and glycerine. As regards sewerage,[1] Tetmajer came to the conclusion that in concentrated condition it had no injurious influence on the hardening process. The seventh volume also describes the effects of mixing cement with certain other minerals such as plaster of Paris, salt, soda or alum, etc., and also mentions the value of some of the Puzzolan cements.

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[1] See the second part of the earlier mentioned *Einheitliche Nomenclatur*, also *Schweiz. Bauzeitung*, 1883, Vol. I, p. 123.

In 1887 he issued a proposition for a new classification of trials for hydraulic cements, and these were printed in 1889 by the Schweiz. Engenieur und Architect Society.

[2] He has earlier written on "Der Schweitz Normal druckapparat für Cement proben." See *Schweiz. Bauzeitung*, 1889, Vol. XIII, p. 7, reprinted in *Thonindustrie Zeitung*, 1889, p. 43, and in which he recommends Amster-Laffous machine and "Luftbreibende Portland cement und die Darrprobe" (see *Schweiz. Bauzeitung*, 1889, Vol. XIV, No. 1).

[3] For earlier mention, see *Schweiz. Bauzeitung*, 1887, Vol. X, pp. 59, 64, 93, and a separate pamphlet in 1889. In reference to those in the sixth volume mentioned experiments he wrote for the Commission, No. 6, "Experiments on shorter methods for testing hydraulic cements."

[4] The pamphlet on the influence of the temperature on the hardening of cement is reprinted in *Thonindustrie Zeitung*, 1893, p. 187, and in *Dingler's Polyt. Journal*, 1894, Vol. CCXCIV, p. 92.

A special treatise gives information of the results attained with trials of beton arches, and finally contains a series of experiments, made earlier in Switzerland, on the behavior of mortar and cement during frost, and the rules to be observed where work must be done under such conditions.

These rules would require too much space to be enumerated here, but are given in *Dingler's Polyt. Journal*, 1895, Vol. 296, p. 215. What is mentioned in regard to slag cement in Vols. VI and VII had already[2] been published before by Tetmajer. At these earlier experiments he showed the importance of the granulation of slag, and that the heavy varieties were more suitable for cement, that the slag when manufactured should issue under heavy pressure and be met with a strong, cold jet of water.

He ascribed the hydraulic properties of the Santorin and Puzzolan cements, to the fact that they were once deposited in the form of volcanic dust, in the water surrounding the volcano.

This sudden cooling resulted in a change of molecules according to Tetmajer's theory, but opinions[3] are divided as to the correctness of this assumption, and Tetmajer holds that the process of granulation is not fully understood.

From the results of his experiments on slag cements can be learned that with increasing proportion between clay and silicium the tendency to cracking increases, the same also taking place if too much lime is present, and that mixtures of slagflour and minerals, comparatively poor in lime, have a lesser tendency to cracking than the mixtures of the flour with minerals richer in lime, but space forbids me to enter further upon these researches. I will only mention that the seventh volume gives description of several important works carried out with slag cement. Among Tetmajer's numerous experiments with cement can be mentioned that for the Commission No. 5 he has demonstrated what influence a greater or smaller pressure would have on the production of the test specimens, and for the Commission No. 7 he has experimented with a more fully described hot water test to determine if by this means it were possible to reduce the time required for the test, but he came to the conclusion that this mode of operation did not give the desired result.[1] From this it will be seen that in this field also a great many researches and experiments are due to Professor L. v. Tetmajer.

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[1] These experiments are incorporated in the reports of Committee No. 11.

[2] Tetmajer has before written on slag cement in *Schweiz. Bauzeitung*, 1886, Vol. VII, p. 83, and has issued a separate pamphlet on this subject, as a supplement to *Notizblatt des Ziegler und Rausbrennervereins*, 1887, Vol. II, p. 80, reprinted in *Dingler's Polyt. Journal*, 1886, Vol. XXVI, p. 530, and 1891, Vol. CCLXXIX, p. 69. See also *Tekn. Foreningens Tidskr.*, 1891-92, p. 57.

[3] See *Dingler's Polyt. Journal*, 1891, Vol. CCLXXIX, p. 69.

Besides the seven volumes and other periodicals, and a great many tests, of which, on account of space, I have only mentioned the most important, Professor Tetmajer has written on: "The theory and use of the slide rule," 1875; "On the external and internal forces, and the graphical determination of the same, in bridge and roof-truss construction," 1875; "Over Culman's bleibende Leistungen," 1882 (delivered before the Society of Natural Science in Zürich); "The value of the Dietzschschen Etagenofens for the Swiss cement industry," 1884; "About the question of the ultimate strength of wrought iron,"[2] in the *Schweiz. Bauzeitung,* 1886, Vol. VIII, p. 141, he has done good work for the introduction of uniformity in test cases, by his appearance before the International Congress, and, finally, in 1889, issued the second half of the first volume of his work on *Baumechanik,* under the name of *Die Augewandte Elasticitäts und Festigkeitslehre,* which has already been touched upon in this writing.

In this work Tetmajer succeeded very plainly to show the importance of the scientific experiments in solving theoretical problems, and he was here in the fortunate position of having any number of experiments conducted by himself to corroborate his assertion. This work is, therefore, without doubt, superior to the earlier ones, and the fact that Bach's excellent work followed so soon after was probably the cause why Tetmajer's work became so little known.

Bach's work by no means makes Tetmajer's book unnecessary, a fact pointed out by Bach himself in the introduction of the book.[3]

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[1] For Erdmenger's tests for the same purpose see *Tekn. Foreningens Tidsk.,* 1894–95, p. 35.

[2] He gives here a formula for the allowable stress in a material, with forces acting on it between certain limits. See also Bach *Die Maschinenelemente,* second edition, 1891–92, p. 62, who does not sanction the use of such formulas.

[3] *Zeitschr. des Ver. d. Eng.,* 1888, pp. 452 and 473.

Of the contents of Tetmajer's work, except what has been previously mentioned, I will only point out his grapho-analythicas studies of the change of form in the different elements of a beam, the calculation of costs, the calculation of the thickness of metal in pipes under internal pressure, the calculation of rollers[1] and bearings for bridge and roof-truss construction, formulæ for rivets[2] on the allowable transverse stress in relation to the tensile and the strength of Delta metal, etc.

There are here and there in his works some passages that can be criticised, but one can well say with Professor Bach that it is quite natural that some of the foundation stones he has laid for this science should not be as well wrought as others, on which work has been spent for years, but nobody will deny, that, in spite of the fact that he has only reached his forty-fifth year, he has accomplished a great deal for the technical science, and one can rest assured that the international conference will for the next year have a very accomplished and energetic president. He has besides another important quality that has always shown its value; nobody could fail to admire the tact by which he prevented any misunderstanding between the French and German representatives in Zürich. Nobody could have been more appropriately selected to bring these two great nations together in peaceful scientific research, than this in Switzerland located Hungarian. It is only then natural to hope that Prof. v. Tetmajer, who, by his tact, succeeded in persuading the French nation to join in the conference, and who guided the same with much energy and amiableness, should continue to reap the fruit of his labors, and be able to continue these researches that have already contributed such valuable results to the technical science.

Prof. v. Tetmajer's biography has never before been written.

When I requested him by letter to direct me where I could study his biography, he answered: "On account of my insignificance and the poor quality of my work, it is natural that nobody should have thought of writing a history of my life or works."

The author has made this attempt to a biography, although considerably outside of his line, and for this reason begs the engineer readers to forbear with such faults and errors that are more than possible under such conditions.

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[1] This calculation is criticised by Professor Bach, in *Zeitschr. des Ver. d. Eng.* 1889, p. 477.

[2] Reprinted in *Dingler's Polyt. Journal*, 1890, Vol. CCLXXVI, p. 218.

SOME PHYSICAL PROPERTIES OF MALLEABLE CAST IRON.

By James H. Wells, Lexington, Kentucky.

IN the following pages some of the physical properties of malleable cast iron will be set forth as determined from tests made in the Mechanical Engineering Laboratory of the State College of Kentucky. The main consideration will be the determination of the relative strengths of malleable cast iron made from various mixtures involving the principal iron used in practice for such work, also to determine the relative strength of cast iron refined and annealed. The specimens used in this series of tests were carefully and conscientiously prepared by Mr. C. C. Heald, Superintendent of the Union Malleable Iron Works, Moline, Ill. A special flask and patterns were made so that the specimens could be poured on end. The size and shape of the test specimens are shown by the accompanying drawing. The iron was melted in large reverberatory furnaces of ten tons capacity, and all of the specimens used in the accompanying tests represent iron taken from practical heats in a modern foundry. The following is a list of the mixtures used in making the test specimens used in this work:

No. 1.

Champion No. 1,	1,200	pounds.
Spring Lake No 2,	1,200	"
Minneapolis No. 2,	2,300	"
Wisconsin No. 3,	1,800	"
Gates and sprues,	4,000	"
	10,500	"

In this heat the amount of refined iron—that is, gates and sprues—is only 38 per cent. of the heat. The iron making the above test specimen was the first that came from the furnace, and therefore contained more of the carbon in the graphitic state.

No. 2.

The iron composing these test specimens were from the same mixture as mixture No. 1, but were made from the last iron to leave the furnace, therefore consisted almost entirely of combined carbon. Hereafter in these pages when the terms "first iron and last iron" are used they will be understood to mean respectively iron containing much carbon in the graphitic state and iron whose carbon is all combined.

No. 3.

Champion No. 1,	1,900	pounds.
Minneapolis No. 2,	1,900	"
Spring Lake No. 2,	1,000	"
Wisconsin No. 3,	1,400	"
Gates and sprues,	5,300	"
	11,500	"

Gates and sprues 46 per cent. of heat. First iron from furnace.

No. 4.

Same heat as No. 3 but last iron from furnace. One bar was annealed from each of the above tests.

No. 5.

From furnace No. 1 :

Minneapolis No. 2,	3,000	pounds
Pioneer No. 2,	1,600	"
Wisconsin No. 3,	2,300	"
Gates and sprues,	4,600	"
	11,500	"

Gates and sprues 40 per cent. of heat. Last iron out of furnace good up in grade with small mottles.

No. 6.

From furnace No. 1 :

Minneapolis No. 2,	2,200	pounds.
Pioneer No 2,	1,200	"
Wisconsin No. 3,	3,000	"
Gates and sprues,	4,600	"
	11,000	"

Gates and sprues 42 per cent. of heat Last iron, grade high when cast.

No. 7.

From furnace No. 1:

Northern No. 2,	1,000	pounds.
Minneapolis No. 2,	2,600	"
Pioneer No. 2.	1,000	"
Wisconsin No. 3,	2,300	"
Gates and sprues,	5,600	"
	12,500	"

Gates and sprues 44 per cent. of heat. Last iron, not high.

No. 8.

Furnace No. 1.

From the same heat and same ladle of iron as No. 7. Square bar chilled entire length on two sides.

No. 9.

From furnace No. 1:

Northern No. 2,	2,500	pounds.
Minneapolis No. 2,	1,500	"
Wisconsin No. 3,	2,300	"
Wisconsin No. 6,	800	"
Gates and sprues,	4,400	"
	11,500	"

Northern iron; last ladle; small mottles, not high. Gates and sprues, 38 per cent. of heat.

No. 10.

From furnace No. 1:

Minnesota No. 2,	1,000	pounds.
Wisconsin No. 2,	2,500	"
Spring Lake No. 3,	2,500	"
Gates and sprues,	5,500	"
	11,500	"

Change in mixture, iron well up. Gates and sprues, 48 per cent. of heat.

No. 11.

From furnace No. 1:

Minnesota No. 2,	1,000	pounds.
Wisconsin No. 2,	1,800	"
Wisconsin No. 3,	1,000	"
Spring Lake No. 3,	1,600	"
Gates and sprues,	4,800	"
	10 200	"

Last iron. Good up. Should make good malleable. Gates and sprues, 48 per cent. of heat.

No. 12.

From furnace No. 1:

Wisconsin No. 2,	2,800	pounds.
Spring Lake No. 3,	1,900	"
Gates and sprues,	4,000	"
	8,700	"

Last ladle. Small heat. Gates and sprues, 46 per cent. of heat.

No. 13.

From furnace No. 2 :

Wisconsin No. 1,	600	pounds.
Wisconsin No. 2,	1,000	"
Minnesota No. 2,	1,700	"
Pioneer No. 3.	900	"
Gates and sprues,	2,800	"
	7,000	"

Trial heat. Iron high. Gates and sprues, 40 per cent. of heat.

No. 14.

From furnace No. 1 :

Minnesota No. 2,	1,200	pounds.
Northern No. 2,	1,100	"
Wisconsin No. 2,	2,400	"
Gates and sprues,	4,000	"
Annealed scrap,	300	"
	9,000	"

Last iron. Good up. Three hundred pounds of annealed scrap weighed in with the gates and sprues make those two items 48 per cent. of heat.

No. 15.

From furnace No. 2 :

Wisconsin No 5,	500	pounds.
Minnosota No. 2,	2,000	"
Northern No. 2,	1,700	"
Gates and sprues,	3,500	"
	7,700	"

Iron entirely up. Gates and sprues, 44 per cent. of heat.

No. 16.

From furnace No. 1 :

Minnesota No. 2,	1,200	pounds.
Northern No. 2,	1,300	"
Wisconsin No. 2,	2,600	"
Wisconsin No. 3,	600	"
Wisconsin No. 6,	400	"
Annealed scrap,	700	"
Gates & sprues,	4,700	"
	11,500	"

Last iron. Good up. Seven hundred pounds of annealed scrap weighed in with gates and sprues, the last two items making 40 per cent. of heat.

No. 17.

From furnace No. 2:

Minnesota No. 2,	1,700 pounds.
Northern No. 2,	2,500 "
Wisconsin No. 3,	1,100 "
Gates and sprues,	2,700 "
	8,000 "

Iron was good up. A piece of ferro aluminum was put in ladle, but not enough to mottle the gate. Gates and sprues, 34 per cent. of heat.

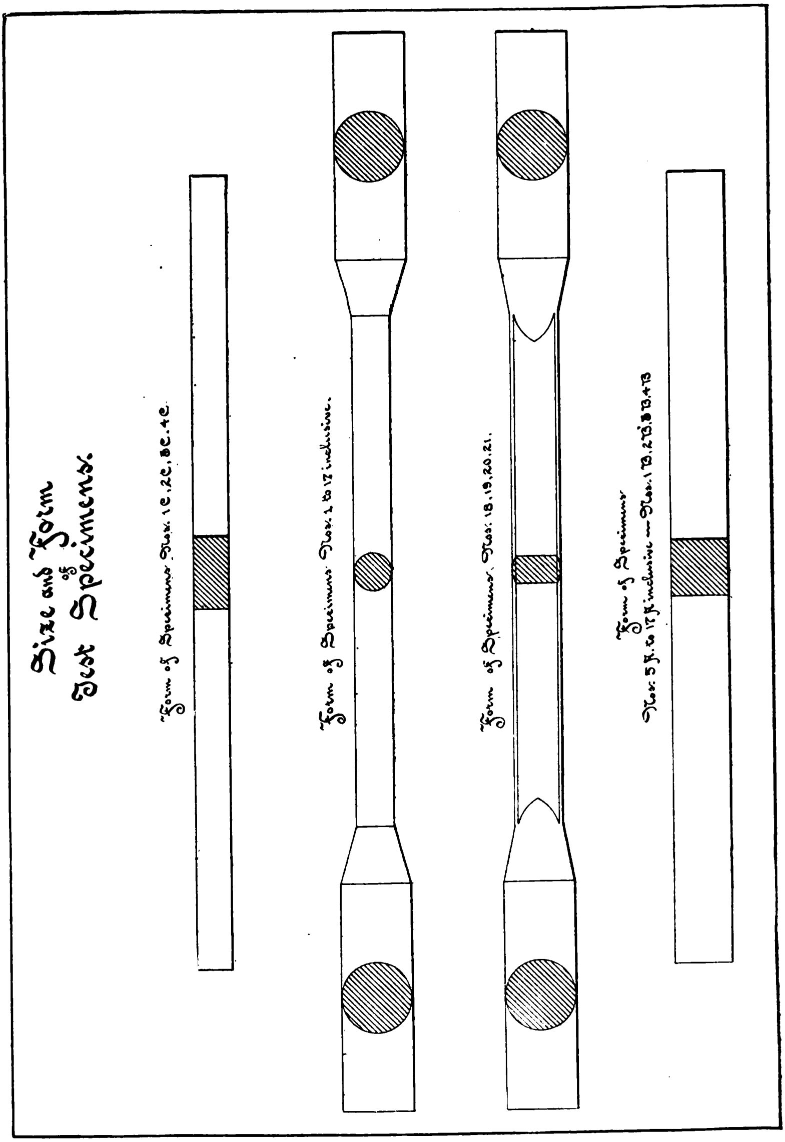
From mixtures No. 1, 2, 3, and 4, four test specimens were made from each. One specimen from each mixture for transverse testing, whose dimensions were practically ½x1¼x14 inches, was made. One specimen was made from each mixture (1, 2, 3, 4), for transverse testing, dimensions being practically 1x1x14 inches. Four specimens were made for tensional testing practically of the dimensions and form indicated by the sketches on the adjacent page from mixtures 1, 2, 3, and 4. Specimens of the laboratory numbers 1, 2, 3, and 4 were not annealed. Specimens whose laboratory numbers are 18, 20, 19, and 21, are annealed and represent respectively irons from mixtures 1, 2, 3, and 4. Below is a tabulated statement concerning specimens tested:

Lab. No.	From what mixture.	How tested.	Annealed or refined.
1,	No. 1,	tensional,	refined.
2,	" 2,	"	"
3,	" 3,	"	"
4,	" 4,	"	"
5,	" 5,	"	annealed.
6,	" 6,	"	"
7,	" 7,	"	"
9,	" 9,	"	"
10,	" 10,	"	"
11,	" 11,	"	"
12,	" 12,	"	"
13,	" 13,	"	"
14,	" 14,	"	"
16,	" 16,	"	"
17,	" 17,	"	"
15,	" 15,	"	"
18,	" 1,	"	"
19,	" 3,	"	"
20,	" 2,	"	"
21,	" 4,	"	"

Lab. No.	From what mixture.	How tested.	Annealed or refined.
5A,	No. 5,	transverse,	annealed.
6A,	" 6,	"	"
7A,	" 7,	"	"
8A,	" 8,	"	"
9A,	" 9,	"	"
10A,	" 10,	"	"
11A,	" 11,	"	"
12A,	" 12,	"	"
13A,	" 13.	"	"
14A,	" 14,	"	"
15A,	" 15,	"	"
16A,	" 16,	"	"
17A,	" 17,	"	"
1B,	" 1,	"	refined,
2B,	" 2,	"	"
3B,	" 3,	"	"
4B,	" 4,	"	"
1C,	" 1,	"	"
2C,	" 2,	"	"
3C,	" 3,	"	"
4C,	" 4,	"	"

The specimen whose laboratory number is 8A was made from the same mixture as No. 7, except that the former was cast between two chills.

Following these pages are sheets giving the data taken in each test, also a report of each test made whether tensional or transverse, and following the reports will be found a series of sketches showing the fractures obtained by breaking each specimen.


Size and Form of Test Specimens.
Form of Specimens Nos: 1C, 2C, 3C, 4C.
Form of Specimens Nos: 1 to 17 inclusive.
Form of Specimens Nos: 18, 19, 20, 21.
Form of Specimens Nos: 5 A. to 17 A inclusive — Nos. 1 B, 2 B, 3 B, 4 B

MECHANICAL LABORATORY, SCHOOL OF MECHANICAL ENGINEERING,
STATE COLLEGE OF KENTUCKY.

LEXINGTON, KY., 1895.

DATA OF TENSIONAL TEST OF CAST IRON ON RIEHLÉ TESTING MACHINE.

Laboratory No. 1. Observer, N. A. NEWTON.

No.	Load.		Micrometer Readings.			Extension.		$d\ell$
	Actual P	Per sq. in. p	I	II	Mean	Actual ℓ	Per in. ϵ	
1	500	1,412	.0106	.0005	.0190	. . .	. . .	. . .
2	1,000	2,824	.0207	.0001	.0108	.0008	.0001	.0008
3	2,000	5,649	.0221	.0003	.0112	.0012	.00015	.0004
4	3,000	8,474	.0235	.0008	.0121	.0021	.00026	.0009
5	4,000	11,299	.0245	.0020	.0132	.0032	.0004	.0011
6	5,000	14,121	.0254	0030	.0142	.0042	.0005	.0010
7	6,000	16,945	.0255	.0041	.0153	.0053	.0006	.0011
8	6,000	18,357	.0275	.0045	.0157	.0057	.0007	.0010
9	7,000	19,774	.0275	.0051	.0163	.0063	.00079	.0006
10	7,500	21,187	.0280	.0055	.0167	.0067	.00083	.0004
11	7,600	21,469	Suddenly broke.					

No. 2 broke at 9 400 lbs., or 28,168 lbs. per square inch.
No 3 " 6,640 " 20,000 " "
No. 4 " 8,900 " 25,141 " "

REPORT OF TENSIONAL TEST.

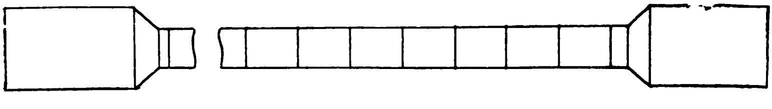
Dimensions.	Original.	Final.
Length, . .	.8 in.	8 0067
Diameter, . .	.665	. . .
Width, . . .	. . .	. . .
Thickness .		. . .
Area, . . .	.332	. . .
Stress.	**Actual.**	**Per sq. in.**
Elastic Limit,	Not deter	minable
Maximum, .	from spe	cimens.
Ultimate, . .	7,600	21.469
Strain.	**Actual.**	**Per in. and per cent.**
Elastic Limit,	. . .	. . .
Maximum, .	. . .	. .
Ultimate, . .	.0067	.00083

Modulus of Elasticity, 28,240,000 lbs per sq. in.
Modulus of Resilience, ft. lbs.

Reduced area per cent. of original.
Actual elongation in 8″, .0067.
Local elongation in ½″ final length.

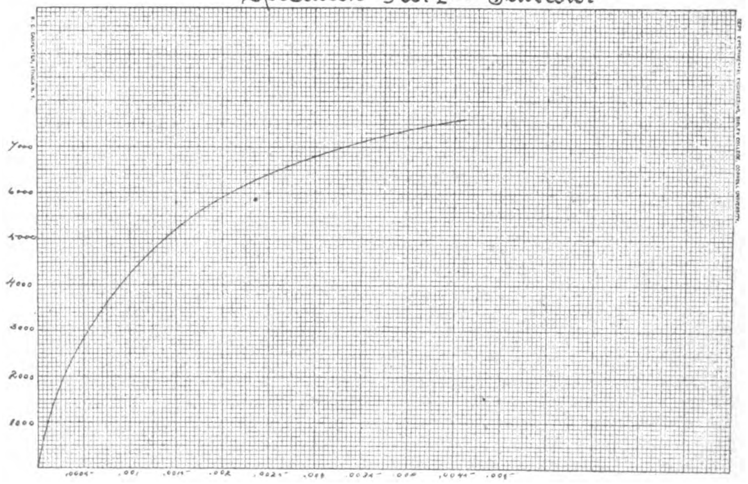
0 1 in.	1-2 in.	2 3 in.	3-4 in.
4-5 in.	5-6 in.	6-7 in.	7-8 in.
8-9 in.	9-10 in.	10-11 in.	11-12 in.
12-13 in.	13-14 in.	14-15 in.	15-16 in.

Equivalent elongation per cent. in 8″, .0008.
Form angle and position of fracture per sketch.
Character of fracture.



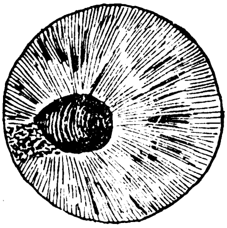
Strain Diagram

Specimen No. 1 — Tension.



Fractures of Specimens subjected to tensional stresses.

No. 1.



The Fractures of specimens Nos. 1, 2, 3 and 4 were bright and crystalline in appearance. Nos. 2, 3, and 4 were free from flaws of any kind.

MECHANICAL LABORATORY, SCHOOL OF MECHANICAL ENGINEERING,
STATE COLLEGE OF KENTUCKY.

LEXINGTON, KY., 1895.

DATA OF TENSIONAL TEST OF CAST IRON (ANNEALED) ON RIEHLÉ TESTING MACHINE.

Laboratory No. 5. Observer, N. A. NEWTON.

No.	Load.		Micrometer Readings.			Extension.		dℓ
	Actual P	Per sq. in. p	I	II	Mean	Actual ℓ	Per in. ε	
1	500	1,428	.0193	.0211	.0202	. . .	. . .	. . .
2	1,000	2,857	.0250	.0170	.0210	.0008	.0001	.0008
3	2,000	5,694	.0278	.0160	.0219	.0017	.0002	.0009
4	3,000	8,541	.0294	.0162	.0228	.0026	.0003	.0009
5	4,000	11,388	.0307	.0170	.0239	.0037	.0004	.0011
6	5,000	14,235	.0316	.0180	.0248	.0046	.0005	.0009
7	6,000	17,082	.0324	.0189	.0256	.0054	.00067	.0008
8	7,000	19,929	.0338	.0194	.0266	.0064	.0008	.0010
9	8,000	22,776	.0357	.0203	.0280	.0078	.0009	.0014
10	9,000	25,623	.0381	.0212	.0287	.0085	.0010	.0007
11	10,000	28,571	.0420	.0226	.0323	.0121	.0015	.0036
12	11,000	31,528	.0507	.0280	.0393	.0191	.0024	.0070
13	12,000	34,385	.0880	.0644	.0767	.0565	.0070	.0374
14	12,500	35,714	. . .	. . .	.06	.0600	.0075	. . .
15	13,000	37,242	. . .	. . .	.10	.1000	.0125	.04
16	14,000	40,099	. . .	. . .	.13	.1300	.0162	.03
17	14,500	41,428	Broke.	. . .	.17	.1700	.0212	.04

REPORT OF TENSIONAL TEST.

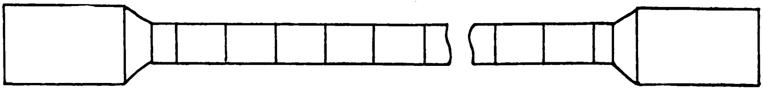
Dimensions.	Original.	Final.
Length, . .	8 in.	8.17
Diameter, .	.668	.556
Width, . . .	. .	.
Thickness, .	. . .	. . .
Area, . . .	.3504	.2427
Stress.	Actual.	Per sq in.
Elastic Limit,	11,000	31,528
Maximum, .	. . .	. . .
Ultimate, . .	14,500	41,428
Strain.	Actual.	Per in. and per cent.
Elastic Limit,	.0191	.0024
Maximum, .	. . .	. . .
Ultimate, . .	.17	.0212

Reduced area per cent. of original, .02.
Actual elongation in 8″, .17.
Local elongation in ½″ final length.

0-1 in.	1-2 in.	2-3 in.	3-4 in.
4-5 in.	5-6 in.	6-7 in.	7-8 in.
8-9 in.	9-10 in.	10-11 in.	11-12 in.
12-13 in.	13-14 in.	14-15 in.	15-16 in.

Equivalent elongation per cent. in 8″, .0212.
Form angle and position of fracture per sketch.
Character of fracture.

Modulus of Elasticity, 14,270,000 lbs. per sq. in.
Modulus of Resilience, ft. lbs.



MECHANICAL LABORATORY, SCHOOL OF MECHANICAL ENGINEERING,
STATE COLLEGE OF KENTUCKY.

LEXINGTON, KY., 1895.

DATA OF TENSIONAL TEST OF CAST IRON (ANNEALED) ON RIEHLÉ TESTING MACHINE.

Laboratory No. 6. Observer, N. A. NEWTON.

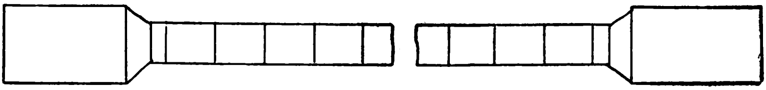
No.	Load.		Micrometer Readings.			Extension.		dλ
	Actual. P	Per sq. in. p	I	II	Mean	Actual. λ	Per in. ε	
1	500	1,408	.0164	.0154	.0159	. . .	. .	. . .
2	1,000	2,845	.0175	.0151	.0163	.0004	.00005	.0004
3	2,000	5,690	.0178	.0166	.0172	.0013	.00017	.0009
4	3,000	8,535	.0175	.0191	.0183	.0024	.0003	.0011
5	4,000	11,380	.0176	.0206	.0191	.0032	.0004	.0008
6	5,000	14,225	.0183	.0221	.0202	.0043	.0005	.0011
7	6,000	17,070	.0188	.0247	.0217	.0058	.0007	.0015
8	7,000	19,915	.0193	.0262	.0227	.0068	.0008	.0010
9	8,000	22,760	.0196	.0270	.0233	.0074	.0009	.0006
10	9 000	25,605	.0206	.0293	.0249	.0090	.0011	.0016
11	10,000	28,450	.0226	.0327	.0276	.0117	.0014	.0027
12	11,000	31,295	.0263	.0395	.0329	.0170	.0021	.0053
13	12,000	34,140	.0586	.0730	.0658	.0497	.0062	.0327
14	13,000	36,985	. . .	. . .	. . .	.08	.01	.0303
15	14,000	39,830	. . .	. . .	. . .	.12	.015	.04
16	14,450	40,704	Broke.	. . .	. .	.16	.02	.04

REPORT OF TENSIONAL TEST.

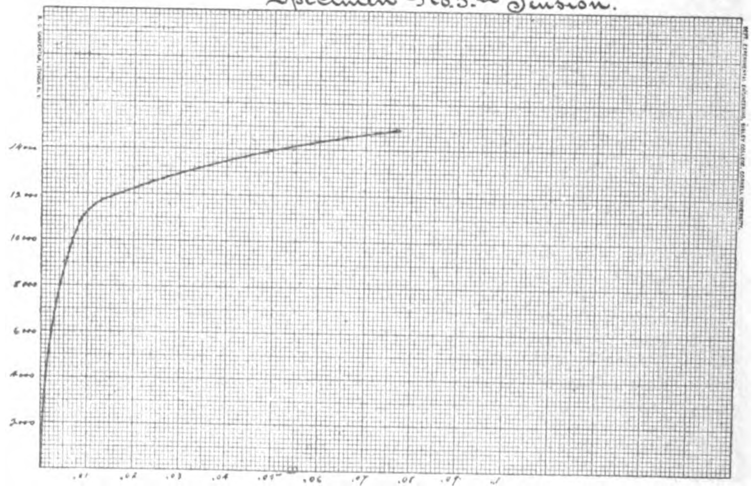
Dimensions.	Original.	Final.
Length, . .	8 in.	8.16
Diameter, . .	.671	.670
Width, . . .	. .	. . .
Thickness, .	. . .	. . .
Area, . .	.3546	.33058
Stress.	Actual.	Per sq. in.
Elastic Limit,	11,000	31,295
Maximum, .		. .
Ultimate, . .	14,450	40,704
Strain.	Actual.	Per in. and per cent.
Elastic Limit,	.017	.002
Maximum, .	. . .	. .
Ultimate, .	.16	.02

Reduced Area per cent. of original, .04.
Actual Elongation in 8″, .16.
Local Elongation in ½″ final length.
0-1 in. 1-2 in. 2-3 in. 3-4 in.
4-5 in. 5-6 in. 6-7 in. 7-8 in.
8-9 in. 9-10 in. 10-11 in. 11-12 in.
12-13 in. 13-14 in. 14-15 in. 15-16 in.
Equivalent Elongation per cent. in 8″, .02.
Form angle and position of fracture per sketch.
Character of fracture.

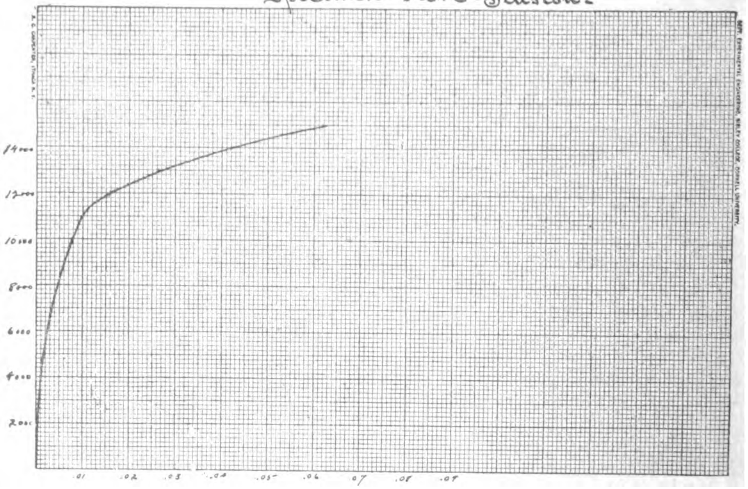
Modulus of Elasticity, 14,225,000 lbs. per sq. in.
Modulus of Resilience, ft. lbs.



Strain Diagram.
Specimen No. 5.— Tension.



Strain Diagram.
Specimen No. 6— Tension.



MECHANICAL LABORATORY, SCHOOL OF MECHANICAL ENGINEERING,
STATE COLLEGE OF KENTUCKY.

LEXINGTON, KY., 1895.

DATA OF TENSIONAL TEST OF CAST IRON (ANNEALED) ON RIEHLÉ TESTING MACHINE.

Laboratory No. 7. Observer, N. A. NEWTON.

No.	Load. Actual. P	Load. Per sq. in. p	Micrometer Readings. I	Micrometer Readings. II	Micrometer Readings. Mean	Extension. Actual λ	Extension. Per in. ε	$d\lambda$
1	500	1,428	.0175	.0073	.0124	. . .	. . .	. . .
2	1,000	2,857	.0182	.0075	.0128	.0004	.00005	.0004
3	2,000	5,694	.0184	.0092	.0138	.0014	.00017	.0010
4	3,000	8,541	.0182	.0112	.0146	.0022	.00027	.0008
5	4,000	11,388	.0185	.0125	.0155	.0031	.00039	.0009
6	5,000	14,235	.0192	.0137	.0164	.0040	.0005	.0009
7	6,000	17,082	.0199	.0147	.0173	.0049	.0006	.0009
8	7,000	19,929	.0210	.0160	.0185	.0061	.0007	.0012
9	8,000	22,776	.0225	.0171	.0196	.0072	.0009	.0011
10	9,000	25 623	.0244	.0184	.0214	.0090	.0011	.0018
11	10,000	28 571	.0275	.0206	.0220	.0096	.0012	.0006
12	11,000	31,528	.0335	.0267	.0301	.0177	.0022	.0011
13	12,000	34 385	.0600	.0532	.0566	.0442	.0055	.0265
14	12,500	35·714	. . .	. . .	. . .	.06	.0075	.0150
15	13,000	37,242	. . .	. . .	. . .	.07	.0087	.01
16	14,000	40,099	. . .	. . .	. . .	.12	.015	.05
17	14.440	41,257	. . .	. . .	. . .	. . .	. . .	. . .

REPORT OF TENSIONAL TEST.

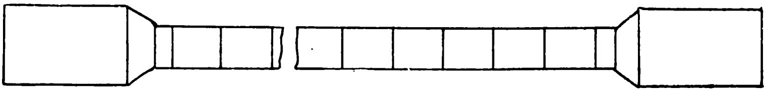
Dimensions.	Original.	Final.
Length, . .	8 in.	8.12
Diameter, .	.679	.670
Width, . . .	. . .	. . .
Thickness, .	. . .	. . .
Area, . . .	.3621	.3575
Stress.	Actual.	Per sq. in.
Elastic Limit,	11,000	31,528
Maximum, .	. . .	. . .
Ultimate, . .	14,400	41,257
Strain.	Actual.	Per in. and per cent.
Elastic Limit,	.0177	.0022
Maximum,	. . .	. . .
Ultimate,	.12	.015

Reduced area per cent. of original, .012.
Actual elongation in 8″, .12.
Local elongation in ½″ final length.

0-1 in.	1-2 in.	2-3 in.	3 4 in.
4-5 in.	5 6 in.	6-7 in.	7-8 in.
8-9 in.	9-10 in.	10-11 in.	11-12 in.
12-13 in.	13-14 in.	14-15 in.	15 16 in.

Equivalent elongation per cent. in 8″. .015.
Form angle and position of fracture per sketch.
Character of fracture.

Modulus of Elasticity, 24,000,000 lbs. per sq. in.
Modulus of Resilience, ft. lbs.



MECHANICAL LABORATORY, SCHOOL OF MECHANICAL ENGINEERING,
STATE COLLEGE OF KENTUCKY.

LEXINGTON, KY., 1895.

DATA OF TENSIONAL TEST OF CAST IRON (ANNEALED) ON RIEHLĖ TESTING MACHINE.

Laboratory No. 9. Observer, N. A. NEWTON.

No.	Load.		Micrometer Readings.			Extension.		$d\lambda$
	Actual P	Per sq. in. p	I	II	Mean	Actual λ	Per in. ε	
1	500	1,310	.0222	.0050	.0136	. . .	. . .	. . .
2	1,000	2,620	.0155	.0152	.0153	.0017	.0002	.0017
3	2,000	5,240	.0115	.0234	.0174	.0028	.0003	.0011
4	3,000	7,860	.0105	.0255	.0180	.0044	.00055	.0016
5	4,000	10,480	.0105	.0297	.0201	.0065	.0008	.0021
6	5,000	13,101	.0109	0335	.0222	.0086	.00107	.0021
7	6,000	15,720	.0110	.0364	.0237	.0101	.0011	.0015
8	7,000	18,340			. . .	.01	.0011	. .
9	8,000	20,960	. . .		. . .	.03	.0025	.02
10	9,500	23,581	.	. . .	. . .	.04	.005	.01
11	10,000	26,202	. . .	. .	. . .	.05	.0062	.01
12	11,000	28,821	. . .	. . .	. . .	.06	.0075	.01
13	12,000	31,440		. . .	. . .	.07	.0087	.01
14	13,000	34,060	. . .	. . .	. .	.08	.01	.01
15	14,000	36,681	. . .		. . .	.12	.0115	.04
16	14,700	39,364	Broke.					

REPORT OF TENSIONAL TEST.

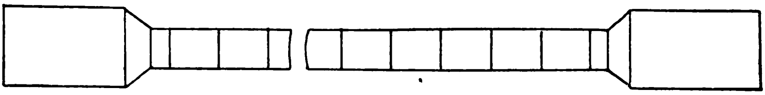
Dimensions.	Original.	Final.
Length, . .	8 in.	8.12
Diameter, . .	.889	.679
Width, . . .	. . .	. . .
Thickness, .	.	. . .
Area, . . .	.3739	.3621
Stress.	**Actual.**	**Per sq. in**
Elastic Limit,	13,000	34,060
Maximum, .	. . .	. . .
Ultimate, . .	147,000	39,364
Strain.	**Actual.**	**Per in. and per cent.**
Elastic Limit,	.08	.01
Maximum, .	. . .	. .
Ultimate, . .	.12	.015

Reduced area per cent. of original, .003.
Actual elongation in 8″, .12.
Local elongation in ½″ final length.

0-1 in.	1-2 in.	2-3 in.	3-4 in.
4-5 in.	5-6 in.	6-7 in.	7-8 in.
8-9 in.	9-10 in.	10-11 in.	11-12 in.
12-13 in.	13-14 in.	14-15 in.	15-16 in.

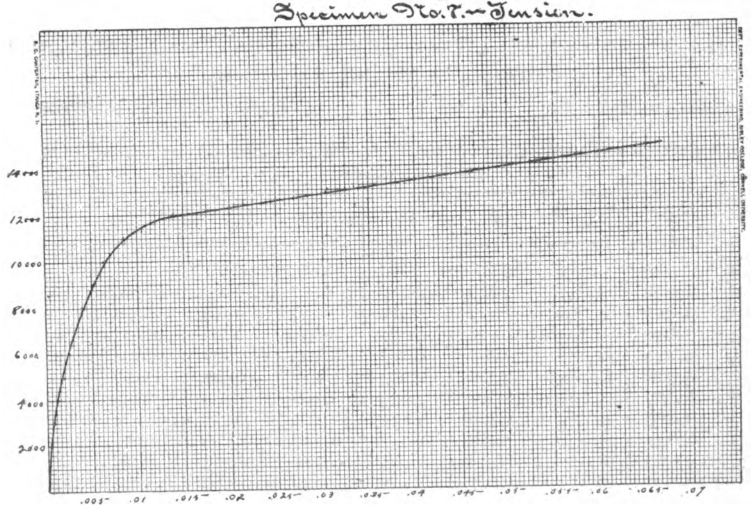
Equivalent elongation per cent in 8″, .01.
Form angle and position of fracture per sketch.
Character of fracture.

Modulus of Elasticity, 13,000,000 lbs per sq. in.
Modulus of Resilience, ft. lbs.



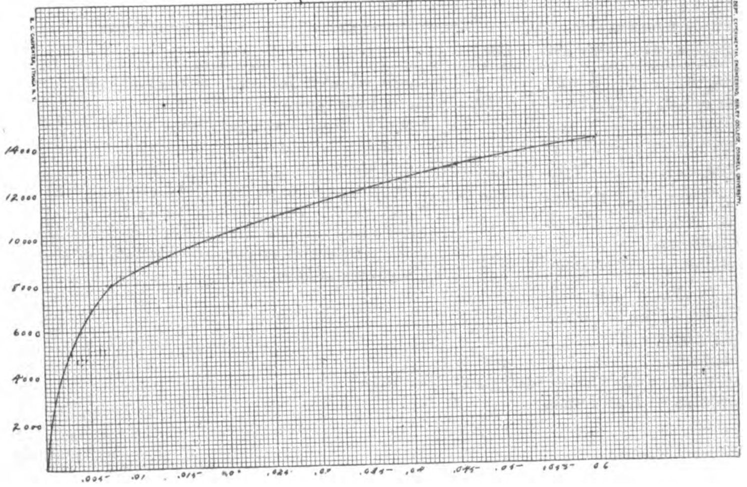
Strain Diagram.

Specimen No. 7.—Tension.



Strain Diagram.

Specimen No. 9—Tension.



MECHANICAL LABORATORY, SCHOOL OF MECHANICAL ENGINEERING,
STATE COLLEGE OF KENTUCKY.

LEXINGTON, KY., 1895.

DATA OF TENSIONAL TEST OF CAST IRON (ANNEALED) ON RIEHLÉ TESTING MACHINE.

Laboratory No. 10. Observer, N. A. NEWTON.

No.	Load.		Micrometer Readings.			Extension.		dλ
	Actual P	Per sq. in p	I	II	Mean	Actual λ	Per in. ε	
1	500	1,428	.0070	.0062	.0066	. . .	. . .	. . .
2	1,000	2,857	.0120	.0027	.0073	.0007	.00008	.0007
3	2,000	5,694	.0148	.0022	.0085	.0019	.0002	.0012
4	3,000	8,541	.0165	.0022	.0093	.0027	.0003	.0008
5	4,000	11,388	.0177	.0029	.0103	.0037	.0004	.0010
6	5,000	14,235	.0191	.0043	.0117	.0057	.0006	.0014
7	6,000	17,082	.0208	.0045	.0126	.0060	.0007	.0009
8	7,000	19,929	.0226	.0057	.0141	.0075	.0009	.0015
9	8,000	22,776	.0247	.0078	.0162	.0096	.0012	.0021
10	9,000	25,623	.0274	.0103	.0188	.0122	.0018	.0026
11	10,000	28,571	.0347	.0157	.0252	.0186	.0023	.0064
12	11,000	31,528	.0509	.0280	.0394	.0228	.0028	.0042
13	12,000	34,385	. . .	. . .	. . .	.06	.0075	.0372
14	13,000	37,242	. . .	. . .	. . .	.11	.0137	.03
15	14,000	40,099	. . .	. . .	. . .	.17	.0212	.06
16	14,200	40,571	Broke.					

REPORT OF TENSIONAL TEST.

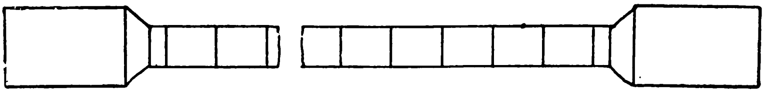
Dimensions.	Original.	Final.
Length, . .	8 in.	8.17
Diameter, .	.669	.664
Width, . . .	. .	. . .
Thickness, .	. . .	. . .
Area, . . .	.3515	.3462
Stress	Actual.	Per sq in.
Elastic Limit,	11,000	31,528
Maximum, .	. .	. . .
Ultimate, . .	14,200	40,571
Strain.	Actual.	Per in. and per cent.
Elastic Limit,	.0228	.0028
Maximum, .	. . .	. . .
Ultimate,	.17	.0212

Modulus of Elasticity, 14,285,000 lbs. per sq. in.
Modulus of Resilience, ft. lbs.

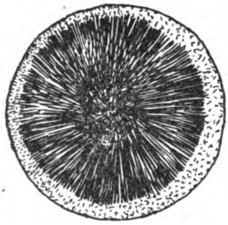
Reduced area per cent. of original, .015.
Actual elongation in 8″, .17.
Local elongation in ½″ final length.

0-1 in.	1-2 in.	2-3 in.	3-4 in.
4-5 in.	5-6 in.	6-7 in.	7-8 in.
8-9 in.	9-10 in.	10-11 in.	11-12 in.
12-13 in.	13-14 in.	14-15 in.	15-16 in.

Equivalent elongation per cent. in 8″, .0212.
Form angle and position of fracture per sketch.
Character of fracture.



No. 5.



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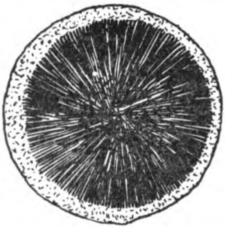
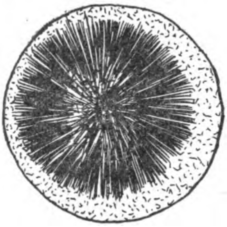


Fractures of Specimens
subjected to tensional stresses.

No. 7.



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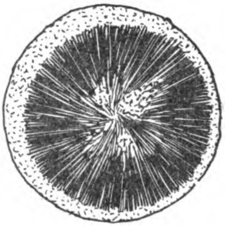
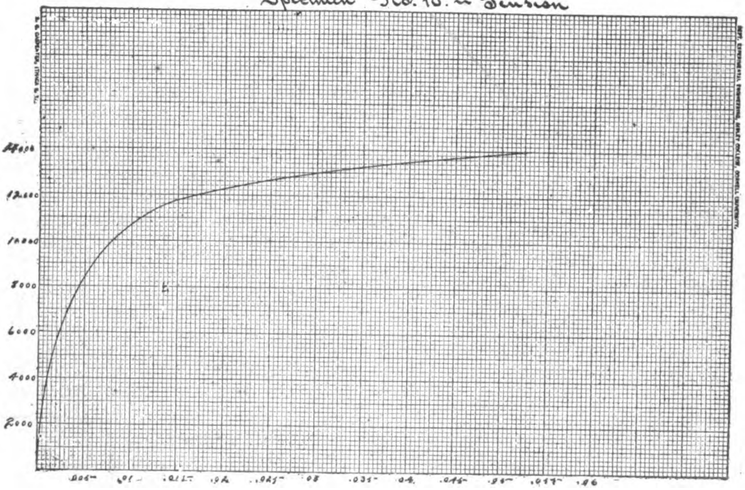


Strain Diagram.
Specimen No. 10. — Tension



MECHANICAL LABORATORY, SCHOOL OF MECHANICAL ENGINEERING,
STATE COLLEGE OF KENTUCKY.

LEXINGTON, KY., 1895.

DATA OF TENSIONAL TEST OF CAST IRON (ANNEALED) ON RIEHLÉ TESTING MACHINE.

Laboratory No. 11. Observer, N. A. NEWTON.

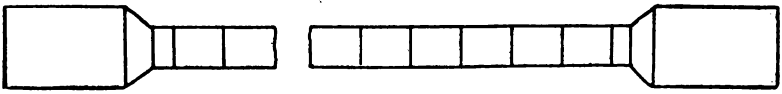
No.	Load.		Micrometer Readings.			Extension.		dλ
	Actual. P	Per sq. in. p	I	II	Mean	Actual λ	Per in. ε	
1	500	1,408	.0120	.0216	.0168	. . .	. . .	. . .
2	1,000	2,845	.0132	.0214	.0173	.0005	.00006	.0005
3	2,000	5,690	.0142	.0220	.0181	.0013	.0001	.0008
4	3,000	8,535	.0146	.0232	.0189	.0021	.0002	.0008
5	4,000	11,380	.0152	.0244	.0198	.0030	.0003	.0009
6	5,000	14,225	.0162	.0257	.0209	.0041	.0005	.0011
7	6,000	17,070	.0170	.0271	.0220	.0052	.0006	.0011
8	7,000	19,915	.0182	.0285	.0233	.0065	.0008	.0013
9	8,000	22,760	.0197	.0301	.0249	.0081	.0010	.0016
10	9,000	25,605	.0224	.0322	.0273	.0105	.0013	.0024
11	10,000	28,450	.0263	.0353	.0308	.0140	.0017	.0035
12	11,000	31,295	.0345	.0430	.0387	.0219	.0027	.0079
13	12,000	34,140	.0600	.0495	.0547	.0379	.0047	.0160
14	13,000	36,985	. . .	. . .	. . .	.11	.0137	.0721
15	14,000	39,830	. . .	. . .	. . .	.15	.0187	.04
16	15,000	42,675	. . .	. . .	. . .	.22	.0275	.07
17	15,300	43,098	Broke.	. . .	. . .	. . .	. . .	. . .

REPORT OF TENSIONAL TEST.

Dimensions.	Original.	Final.
Length, . .	8 in.	8.22
Diameter, .	.671	.669
Width, . . .	. . .	. . .
Thickness, .	. . .	. . .
Area, . . .	.3536	.3515
Stress.	Actual.	Per sq. in.
Elastic Limit,	11,000	28,450
Maximum, .	. . .	. . .
Ultimate, . .	15,300	43,098
Strain.	Actual.	Per in. and per cent.
Elastic Limit,	.0219	.0027
Maximum, .	. . .	. . .
Ultimate, . .	.22	.0275

Reduced area per cent. of original, .006.
Actual elongation in 8″, .22.
Local elongation in ½″ final length.
0-1 in. 1-2 in. 2-3 in. 3 4 in.
4-5 in. 5-6 in. 6-7 in. 7-8 in.
8-9 in. 9-10 in. 10-11 in. 11-12 in.
12-13 in. 13-14 in. 14-15 in. 15-16 in.
Equivalent elongation per cent. in 8″. .0275.
Form angle and position of fracture per sketch.
Character of fracture.

Modulus of Elasticity, 12,300,000 lbs. per sq. in.
Modulus of Resilience, ft. lbs.



MECHANICAL LABORATORY, SCHOOL OF MECHANICAL ENGINEERING,
STATE COLLEGE OF KENTUCKY.

LEXINGTON, KY., 1895.

REPORT OF TENSIONAL TESTS OF CAST IRON (ANNEALED).

Laboratory No. 12. Observer, N. A. NEWTON.

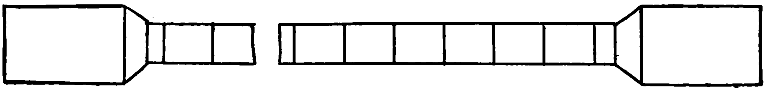
Dimensions.	Original.	Final.
Length, . .	8 in.	8.16
Diameter, . .	.673	.664
Width, . . .	. .	. . .
Thickness, .	. . .	. . .
Area, . . .	.3577	.3462
Stress.	Actual.	Per sq. in.
Elastic Limit,	11,000	33,898
Maximum, .		. .
Ultimate, . .	15,700	44,101
Strain.	Actual.	Per in. and per cent.
Elastic Limit,	.0174	.0021
Maximum, .	. . .	. .
Ultimate, . .	.16	.02

Modulus of Elasticity, 14,040,000 lbs. per sq. in.
Modulus of Resilience, ft. lbs.

Reduced area per cent. of original, .025.
Actual elongation in 8″, .16.
Local elongation in ½″ final length.

0-1 in.	1-2 in.	2-3 in.	3-4 in.
4-5 in.	5-6 in.	6-7 in.	7-8 in.
8-9 in.	9-10 in.	10-11 in.	11-12 in.
12-13 in.	13-14 in.	14-15 in.	15-16 in.

Equivalent elongation per cent. in 8″, .02.
Form angle and position of fracture per sketch.
Character of fracture.



Laboratory No. 13. Observer, M. A. NEWTON.

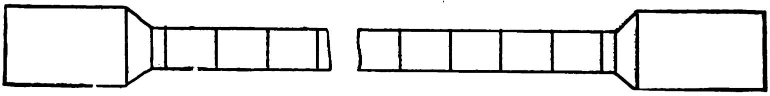
Dimensions.	Original.	Final.
Length, . .	8 in.	8.3
Diameter, . .	.682	.666
Width, .	. . .	. . .
Thickness, .	. . .	. . .
Area, . . .	.3653	.3455
Stress.	Actual.	Per sq. in.
Elastic Limit,	11,000	30,137
Maximum, .	. . .	. . .
Ultimate, . .	15,150	41,506
Strain.	Actual.	Per in. and per cent.
Elastic Limit,	.0268	.0033
Maximum, .	. . .	. . .
Ultimate, . .	.3	.037

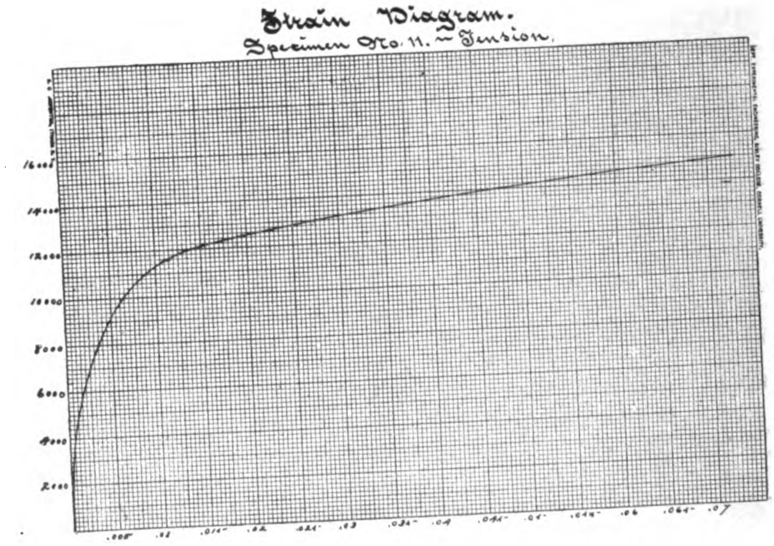
Modulus of Elasticity, 9,130,000 lbs. per sq. in.
Modulus of Resilience, ft. lbs.

Actual area per cent. of original, .05.
Actual elongation in 8″, .3.
Local elongation in ½″ final length.

0-1 in.	1-2 in.	2-3 in.	3-4 in.
4-5 in.	5-6 in.	6-7 in.	7-8 in.
8-9 in.	9-10 in.	10-11 in.	11-12 in.
12-13 in.	13-14 in.	14-15 in.	15-16 in.

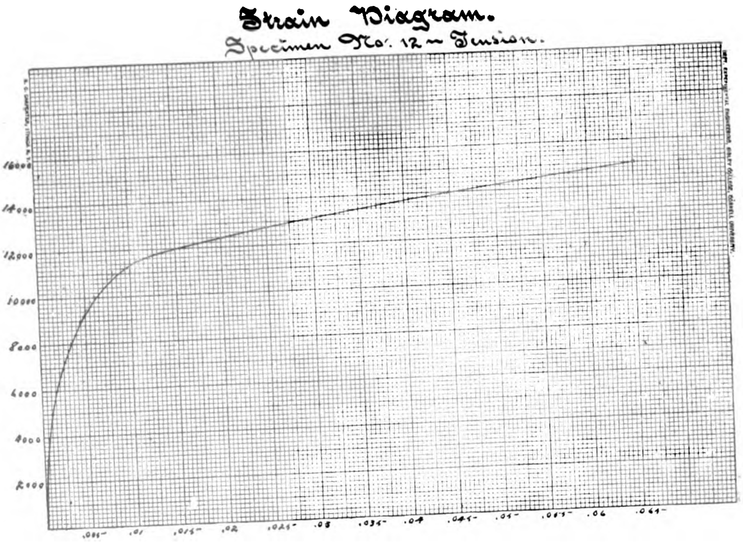
Equivalent elongation per cent. in 8″, .037.
Form angle and position of fracture per sketch.
Character of fracture.





Strain Diagram.

Specimen No. 11. ~ Tension.

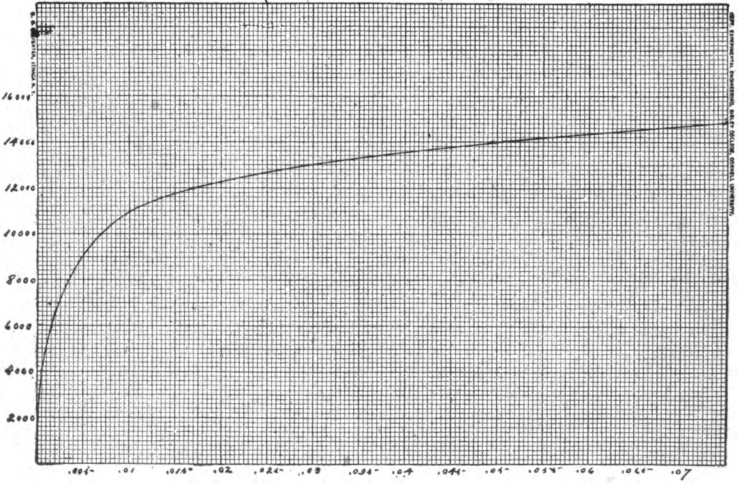


Strain Diagram.

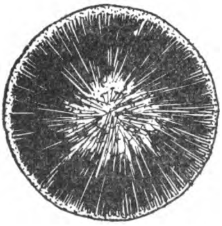
Specimen No. 12 ~ Tension.

Strain Diagram.

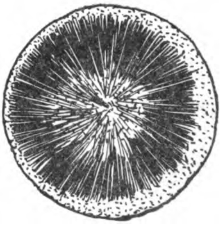
Specimen No. 13 – Tension



No. 10.

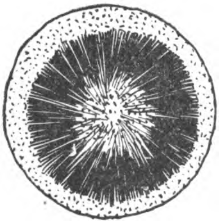


No. 11.

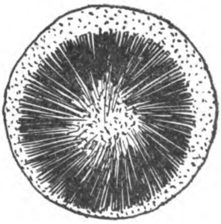


Fractures of Specimens subjected to tensional stresses.

No. 12.



No. 13.



MECHANICAL LABORATORY, SCHOOL OF MECHANICAL ENGINEERING, STATE COLLEGE OF KENTUCKY.

LEXINGTON, KY., 1895.

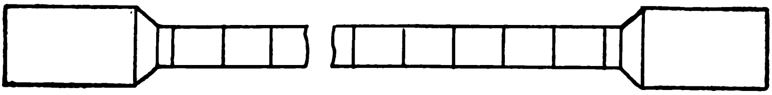
REPORT OF TENSIONAL TESTS OF CAST IRON (ANNEALED).

Laboratory No. 14. Observer, N. A. NEWTON.

Dimensions.	Original.	Final.
Length, . .	8 in.	8.2
Diameter, . .	.669	.663
Width, . . .	. . .	. . .
Thickness, .	. . .	. . .
Area, . . .	.3508	.3442
Stress.	Actual.	Per sq. in.
Elastic Limit,	11,000	31,528
Maximum, .	. . .	. . .
Ultimate, . .	15,145	43,271
Strain.	Actual.	Per in. and per cent.
Elastic Limit,	.0226	.0028
Maximum, .	. . .	. . .
Ultimate, . .	.20	.025

Reduced area per cent. of original, .02.
Actual elongation in 8″, .2.
Local elongation in ½″ final length.
0-1 in. 1-2 in. 2-3 in. 3-4 in.
4-5 in. 5-6 in. 6-7 in. 7-8 in.
8-9 in. 9-10 in. 10-11 in. 11-12 in.
12-13 in. 13-14 in. 14-15 in. 15-16 in.
Equivalent elongation per cent. in 8″, .025.
Form angle and position of fracture per sketch.
Character of fracture.

Modulus of Elasticity, 11,400,000 lbs. per sq. in.
Modulus of Resilience, ft. lbs.

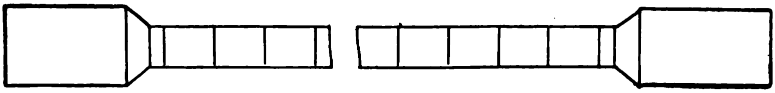


Laboratory No. 15. Observer, N. A. NEWTON.

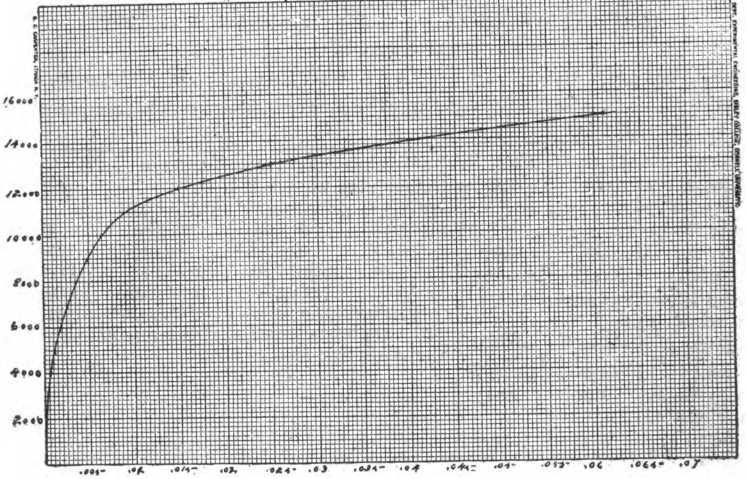
Dimensions.	Original.	Final.
Length, . .	8 in.	8.24
Diameter, . .	.677	.666
Width, . . .	. . .	. . .
Thickness, .	. . .	. . .
Area, . . .	.3609	.3455
Stress.	Actual.	Per sq. in.
Elastic Limit,	11,000	30,555
Maximum, .	. . .	. . .
Ultimate, . .	16 370	47,750
Strain.	Actual.	Per in. and per cent.
Elastic Limit,	.0159	.0019
Maximum, .	. . .	. . .
Ulimate, . .	.24	.03

Reduced area per cent. of original, .04.
Actual elongation in 8″, .24.
Local elongation in ½″ final length.
0-1 in. 1-2 in. 2-3 in. 3-4 in.
4-5 in. 5-6 in. 6-7 in. 7-8 in.
8-9 in. 9-10 in. 10-11 in. 11-12 in.
12-13 in. 13-14 in. 14-15 in. 15-16 in.
Equivalent elongation per cent. in 8″, .033.
Form angle and position of fracture per sketch.
Character of fracture.

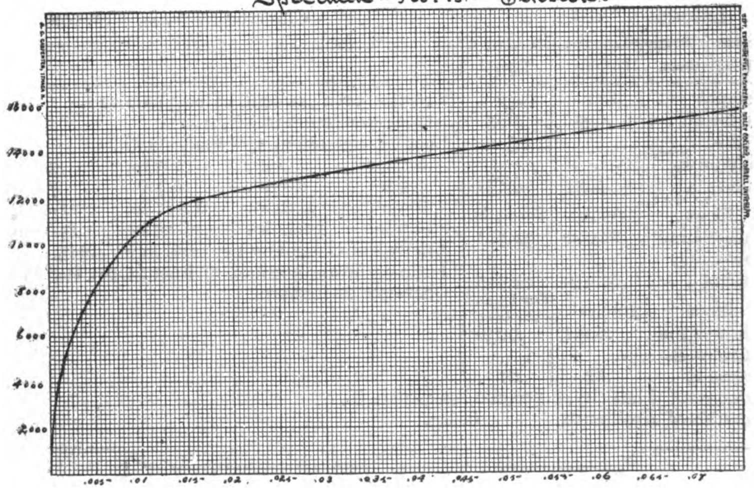
Modulus of Elasticity, 12,200,000 lbs. per sq. in.
Modulus of Resilience, ft. lbs.



Strain Diagram.
Specimen No. 14.—Tension.



Strain Diagram.
Specimen No. 15.—Tension.



MECHANICAL LABORATORY, SCHOOL OF MECHANICAL ENGINEERING,
STATE COLLEGE OF KENTUCKY.

LEXINGTON, KY., 1895.

REPORT OF TENSIONAL TESTS OF CAST IRON (ANNEALED).

Laboratory No. 16. Observed by N. A. NEWTON.

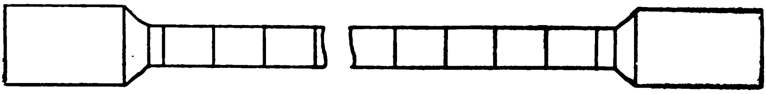
Dimensions.	Original.	Final.
Length, . .	8 in.	8.29
Diameter, . .	.66	.659
Width, . . .	.	. . .
Thickness, .	. . .	. . .
Area, . . .	.3485	.3410
Stress.	Actual.	Per sq. in.
Elastic Limit,	11,000	31,581
Maximum, .	. . .	. . .
Ultimate, . .	162,000	46,600
Strain.	Actual.	Per in. and per cent.
Elastic Limit,	.0206	.0017
Maximum, .	. . .	. . .
Ultimate, . .	.29	.0396

Reduced area per cent. of original, .021.
Actual elongation in 8″, .29.
Local elongation in ½″ final length.

0-1 in.	1-2 in.	2-3 in.	3-4 in.
4-5 in.	5-6 in.	6-7 in.	7-8 in.
8-9 in.	9-10 in.	10-11 in.	11-12 in.
12-13 in.	13-14 in.	14-15 in.	15-16 in.

Equivalent elongation per cent. in 8″, .0396.
Form angle and position of fracture per sketch.
Character of fracture.

Modulus of Elasticity, 14,335,000 lbs. per sq. in.
Modulus of Resilience, ft. lbs.



Laboratory No. 17. Observed by N. A. NEWTON.

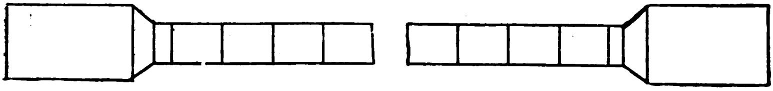
Dimensions.	Original.	Final.
Length, . .	8 in.	8.12
Diameter, . .	.667	.663
Width, . . .	. . .	. . .
Thickness, .	. . .	. . .
Area, . . .	.3494	.3452
Stress.	Actual.	Per sq. in.
Elastic Limit,	11,000	31,581
Maximum, .	. . .	. . .
Ultimate, . .	15,330	44,045
Strain.	Actual.	Per in. and per cent.
Elastic Limit,	.0291	.0036
Maximum, .	. . .	. .
Ultimate, . .	.12	.015

Reduced area per cent. of original, .012.
Actual elongation in 8″, .12.
Local elongation in ½″ final length.

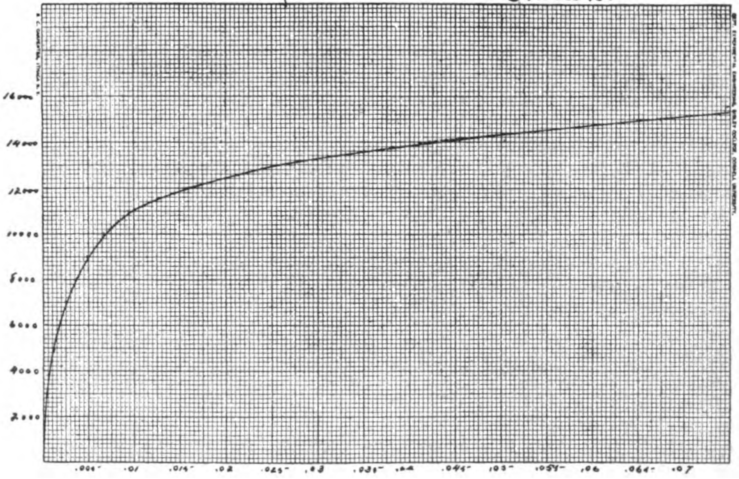
0-1 in.	1-2 in.	2-3 in.	3-4 in.
4-5 in.	5-6 in.	6-7 in.	7-8 in.
8-9 in.	9-10 in.	10-11 in.	11-12 in.
12-13 in.	13-14 in.	14-15 in.	15-16 in.

Equivalent elongation per cent. in 8″, .015.
Form angle and position of fracture per sketch.
Character of fracture.

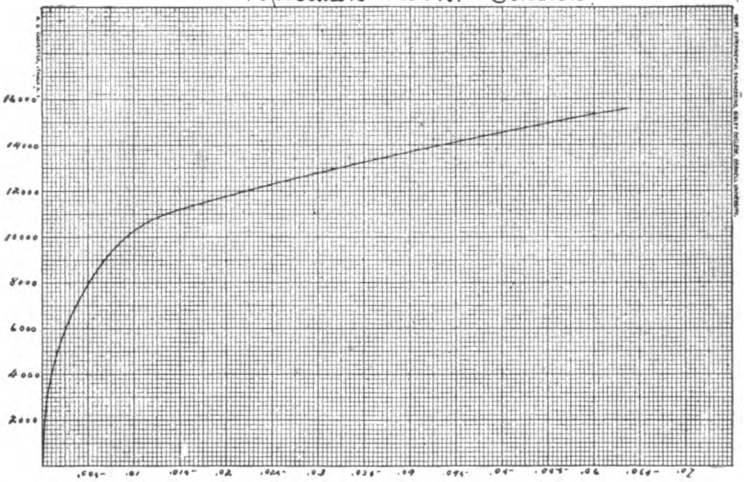
Modulus of Elasticity, 9,550,000 lbs. per sq. in.
Modulus of Resilience, ft. lbs.



Strain Diagram.
Specimen No. 16 — Tension.



Strain Diagram.
Specimen No. 17. — Tension.



MECHANICAL LABORATORY, SCHOOL OF MECHANICAL ENGINEERING,
STATE COLLEGE OF KENTUCKY.

LEXINGTON, KY., 1895.

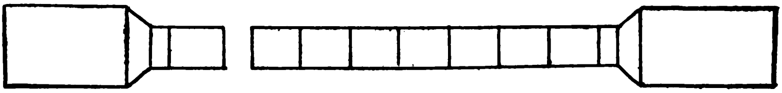
REPORT OF TENSIONAL TESTS OF CAST IRON (ANNEALED).

Laboratory No. 18. Observed by N. A. NEWTON.

Dimensions.	Original.	Final.
Length, . .	8 in.	8.07
Diameter, . .	.794	.790
Width, . . .	. . .	. . .
Thickness, .	.533	.529
Area, . . .	.40	.3968
Stress.	Actual.	Per sq. in.
Elastic Limit,	11,500	28,750
Maximum, .	. . .	. . .
Ultimate, . .	14,420	36,050
Strain.	Actual.	Per in. and per cent.
Elastic Limit,	.0206	.00257
Maximum, .	.07	.0087
Ultimate, . .	.	. . .

Reduced area per cent. of original, .008.
Actual elongation in 8″, .07.
Local elongation in ½″ final length.
0-1 in. 1-2 in. 2-3 in. 3-4 in.
4-5 in. 5-6 in. 6-7 in. 7-8 in.
8-9 in. 9-10 in. 10-11 in. 11-12 in.
12-13 in. 13-14 in. 14-15 in. 15-16 in.
Equivalent elongation per cent. in 8″, .008
Form angle and position of fracture per sketch.
Character of fracture.

Modulus of Elasticity, 10,000,000 lbs. per sq. in.
Modulus of Resilience, ft. lbs.

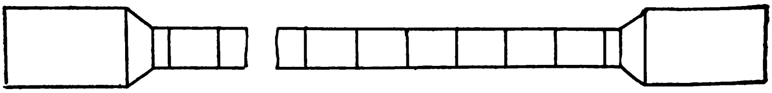


Laboratory No. 19. Observed by N. A. NEWTON.

Dimensions.	Original.	Final.
Length, .	8 in.	8.08
Diameter, . .	.81775	.817
Width, . . .	. . .	.
Thickness, .	.551	.549
Area, . . .	.40	.3984
Stress.	Actual.	Per sq. in.
Elastic Limit,	13,000	32,500
Maximum, .	.	. . .
Ultimate, . .	15,190	37,975
Strain	Actual.	Per in. and per cent.
Elastic Limit,	.0301	.0037
Maximum,	. . .	. . .
Ultimate, .	.08	.01

Reduced area per cent. of original, .004.
Actual elongation in 8″, .08.
Local elongation in ½″ final length.
0-1 in. 1-2 in. 2-3 in. 3-4 in.
4-5 in. 5-6 in. 6-7 in. 7-8 in.
8-9 in. 9-10 in. 10-11 in. 11-12 in.
12-13 in. 13-14 in. 14-15 in. 15-16 in.
Equivalent elongation per cent. in 8″, .009.
Form angle and position of fracture per sketch.
Character of fracture. Flaw on one.

Modulus of Elasticity, 12,500,000 lbs. per sq. in.
Modulus of Resilience, ft. lbs.



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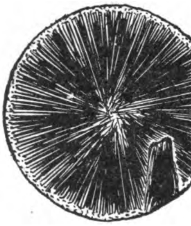

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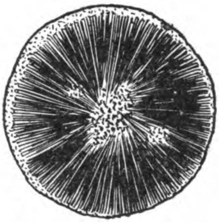
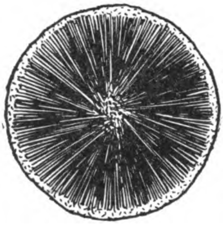
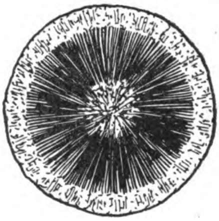


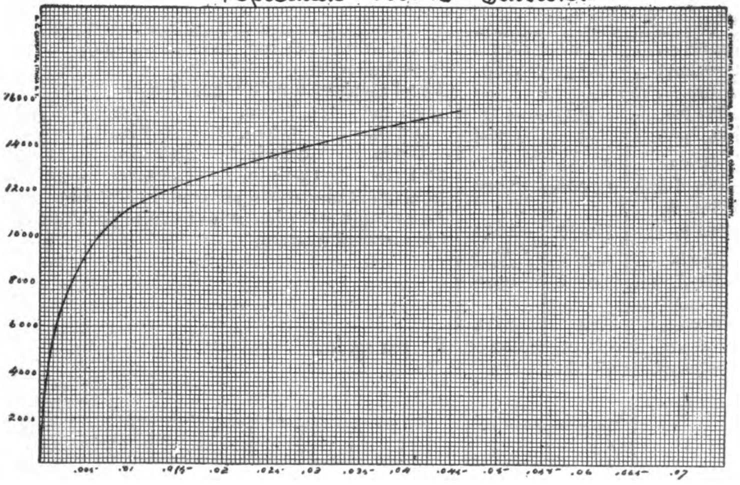
Fractures of Specimens
subjected to tensional stresses.

No. 16.



No. 17.





Strain Diagram.
Specimen No. 18 – Tension.

MECHANICAL LABORATORY, SCHOOL OF MECHANICAL ENGINEERING, STATE COLLEGE OF KENTUCKY.

LEXINGTON, KY., 1895.

REPORT OF TENSIONAL TESTS OF CAST IRON (ANNEALED).

Laboratory No. 20. Observed by N. A. NEWTON.

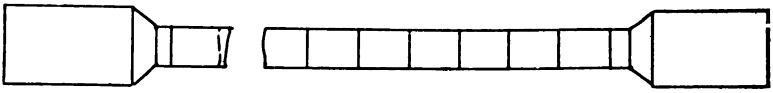
Dimensions.	Original.	Final.
Length,	8 in.	8.06
Diameter,	.807	.796
Width,	. . .	. . .
Thickness,	.533	.530
Area.	.395	.345
Stress	Actual.	Per sq. in.
Elastic Limit,	12,000	30,768
Maximum,		. . .
Ultimate,	13,630	34,948
Strain.	Actual.	Per in. and per cent.
Elastic Limit,	.0258	.0032
Maximum,	.06	.0075
Ultimate,	. . .	. . .

Reduced area per cent. of original, .014.
Actual elongation in 8″, .06.
Local elongation in ½″ final length.

0-1 in	1-2 in.	2-3 in.	3-4 in.
4-5 in.	5-6 in.	6-7 in.	7-8 in.
8-9 in.	9-10 in.	10-11 in.	11-12 in.
12-13 in.	13-14 in.	14-15 in.	15-16 in.

Equivalent elongation per cent. in 8″, .007.
Form angle and position of fracture per sketch.
Character of fracture.

Modulus of Elasticity, 12,200,000 lbs. per sq. in.
Modulus of Resilience, ft. lbs.



Laboratory No. 21. Observed by N. A. NEWTON.

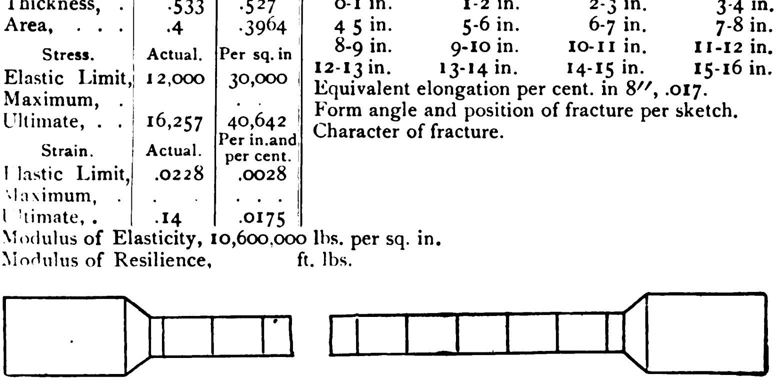
Dimensions.	Original.	Final.
Length,	8 in.	8.14
Diameter,	.794	.789
Width,	. . .	. . .
Thickness,	.533	.527
Area,	.4	.3964
Stress.	Actual.	Per sq. in
Elastic Limit,	12,000	30,000
Maximum,		. .
Ultimate,	16,257	40,642
Strain.	Actual.	Per in. and per cent.
Elastic Limit,	.0228	.0028
Maximum,	. . .	. . .
Ultimate,	.14	.0175

Reduced area per cent. of original, .009.
Actual elongation in 8″, .14.
Local elongation in ½″ final length.

0-1 in.	1-2 in.	2-3 in.	3-4 in.
4-5 in.	5-6 in.	6-7 in.	7-8 in.
8-9 in.	9-10 in.	10-11 in.	11-12 in.
12-13 in.	13-14 in.	14-15 in.	15-16 in.

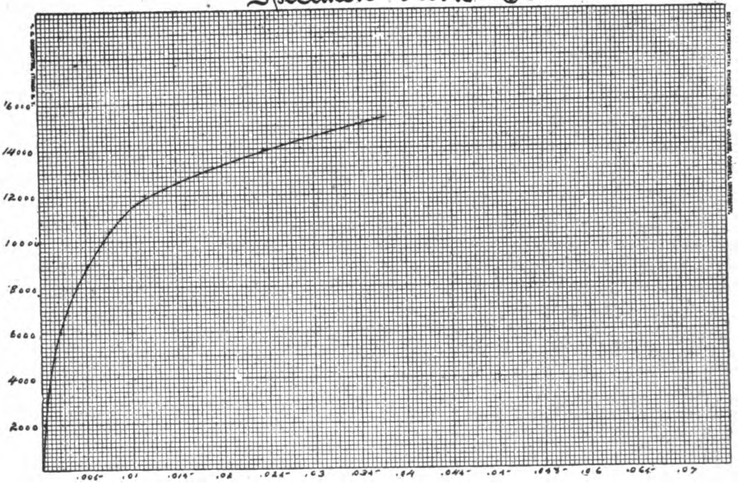
Equivalent elongation per cent. in 8″, .017.
Form angle and position of fracture per sketch.
Character of fracture.

Modulus of Elasticity, 10,600,000 lbs. per sq. in.
Modulus of Resilience, ft. lbs.



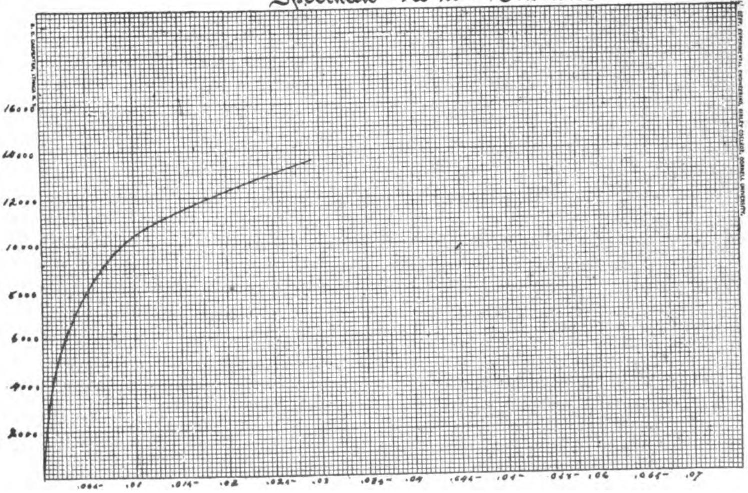
Strain Diagram.

Specimen No. 19 — Tension.

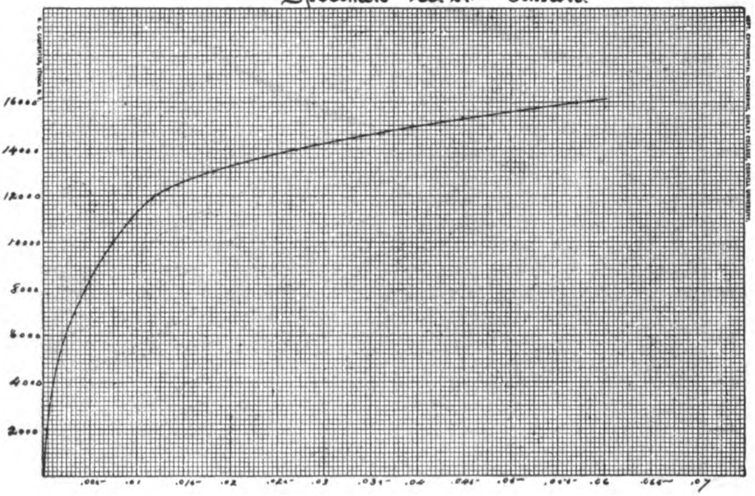


Strain Diagram.

Specimen No. 20 — Tension.



Strain Diagram.
Specimen No. 21.—Tension.



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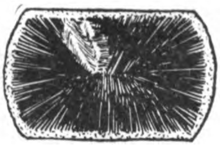

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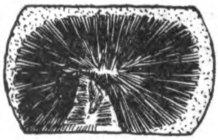
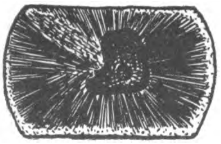


Fractures of Specimens
subjected to tensional stresses.

No. 20.



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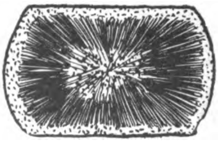


Mechanical Laboratory, School of Mechanical Engineering,
State College of Kentucky.

Lexington, Ky., 1895.

DATA OF TRANSVERSE TEST OF CAST IRON (ANNEALED).

Length between supports, 12 in.

Laboratory No. 5A. Observer, J. V. Faulkner.

No.	Load. P.	Deflection.		No.	Load. P.	Deflection.	
		Reading.	a			Reading.	a
1	100	.836	....	21	2,200	.8810	.0035
2	200	.838	.002	22	2,300	.8840	.0030
3	300	.8405	.0025	23	2,400	.8900	.0060
4	500	.8428	.0023	24	2,500	.8930	.0030
5	600	.8450	.0022	25	2,600	.8980	.0050
6	700	.8485	.0035	26	2,700	.9035	.0055
7	800	.8510	.0025	27	2,800	.9095	.0060
8	900	.8525	.0015	28	2,900	.9180	.0085
9	1,000	.8542	.0017	29	3,000	.9280	.0100
10	1,100	.8570	.0028	30	3,100	.9420	.0140
11	1,200	.8590	.0020	31	3,200	.9560	.0140
12	1,300	.8610	.0020	32	3,300	.9790	.0230
13	1,400	.8630	.0020	33	3,400	1.00	.0210
14	1,500	.8650	.0020	34	3,500	1.0280	.0280
15	1,600	.8670	.0020	35	3,600	1.0530	.0250
16	1,700	.8680	.0010	36	3,700	1.0780	.0250
17	1,800	.8705	.0025	37	3,800	1.1220	.0440
18	1,900	.8740	.0035	38	3,900	1.1570	.0350
19	2,000	.8770	.0030	39	4,000	1.2020	.0450
20	2,100	.8785	.0015				

REPORT OF TRANSVERSE TEST.

Laboratory No. 5A.

Load applied, 4,000 lbs.

Dimensions.		Symbol.
Length,	12 ins.	I
Breadth,	1.027 "	b
Height,	1.022 "	h
Maximum fibre distance,	.511 "	e
Moment of inertia,	.0913	I

Load.		Actual.	Per □″ in Outer Fibre.
Elastic limit,	2,287.89	2,400	38,400
Maximum,	38,131.55	4,000	63,980

Deflection	Elastic limit,	.054
	Maximum,	.336
Modulus of Elasticity,		21,430,000

**MECHANICAL LABORATORY, SCHOOL OF MECHANICAL ENGINEERING,
STATE COLLEGE OF KENTUCKY.**

LEXINGTON, KY., 1895.

REPORT OF TRANSVERSE TESTS OF CAST IRON (ANNEALED).

Load applied, 4,200 lbs.

Laboratory No. 6A. Observers, J. W. MOORE, J. V. FAULKNER.

Dimensions.			Symbol.
Length,	12	ins.	l
Breadth,	1.047	"	b
Height,	1.039	"	h
Maximum fibre distance,	.5695	"	e
Moment of inertia,	.0978		I

Load.		Actual.	Per □″ in Outer Fibre.
Elastic limit,	2,389.70	2,600	41,432
Maximum,	3,860.29	4,200	67,005

DEFLECTION	Elastic limit,	.0537
	Maximum,	.4505
MODULUS OF ELASTICITY,		18,940,000

Laboratory No. 7A. Observers, J. W. MOORE, J. V. FAULKNER.

Load applied, 4,200 lbs.

Dimensions.			Symbol.
Length,	12	ins.	l
Breadth,	1.034	"	b
Height,	1.037	"	h
Maximum fibre distance,	.5185	"	e
Moment of inertia,	.0929		I

Load.		Actual.	Per □″ in Outer Fibre.
Elastic limit.	1,921	2,100	35,162
Maximum,	3,842	4,200	70,324

DEFLECTION	Elastic limit,	.0431
	Maximum,	.4424
MODULUS OF ELASTICITY,		21,804,025

MECHANICAL LABORATORY, SCHOOL OF MECHANICAL ENGINEERING,
STATE COLLEGE OF KENTUKY.

LEXINGTON, KY., 1895.

REPORT OF TRANSVERSE TESTS OF CAST IRON (ANNEALED).

Load applied, 6,925 lbs.

Laboratory No. 8A. Observers, J. W. MOORE, J. V. FAULKNER.

Dimensions.			Symbol.
Length,	12	ins.	I
Breadth,	1.0506	"	b
Height,	1.176	"	h
Maximum fibre distance,	.588	"	e
Moment of inertia,	.12204		I

Load.		Actual.	Per □″ in Outer Fibre.
Elastic limit,	2,891	3,400	48,944
Maximum,	5,887	6,925	99,687

DEFLECTION { Elastic limit, .0706
DEFLECTION { Maximum, 1.8568
MODULUS OF ELASTICITY, 18,619,960

Load applied, 4,350 lbs.

Laboratory No. 9A. Observers, J. W. MOORE, J. V. FAULKNER.

Dimensions.			Symbol.
Length,	12	ins.	I
Breadth,	1.024	"	b
Height,	1.030	"	h
Mamimum fibre distance,	.515	"	e
Moment of inertia,	.0932		I

Load.		Actual.	Per □″ in Outer Fibre.
Elastic limit,	2843.7	3,000	49,731
Maximum,	4123.2	4,350	72,110

DEFLECTION { Elastic limit, .0555
DEFLECTION { Maximum, .4013
MODULUS OF ELASTICITY, 21,165,206

MECHANICAL LABORATORY, SCHOOL OF MECHANICAL ENGINEERING,
STATE COLLEGE OF KENTUCKY.

LEXINGTON, KY., 1895.

REPORT OF TENSIONAL TESTS OF CAST IRON (ANNEALED).

Load applied, 4,800 lbs.

Laboratory No. 10A. Observers, J. W. MOORE, J. V. FAULKNER.

Dimensions.			Symbol.
Length,	12	ins.	I
Breadth,	1.029	"	b
Height,	1.02	"	h
Maximum fibre distance,	.51	"	e
Moment of inertia,	.0893		I

Load.		Actual.	Per □″ in Outer Fibre.
Elastic limit,	2,669	2,800	47,973
Maximum,	4,575	4,800	82,239

DEFLECTION	Elastic limit,	.0655
	Maximum,	.9236
MODULUS OF ELASTICITY,		20,056,520

Laboratory No. 11A. Observers, D. M. CASE, J. V. FAULKNER.

Load applied, 3,900 lbs.

Dimensions.			Symbol.
Length,	12	ins.	I
Breadth,	1.029	"	b
Height,	1.018	"	h
Maximum fibre distance,	.504	"	e
Moment of inertia,	.0904		I

Load.	Actual.	Per □″ in Outer Fibre.
Elastic limit,	2,400	40,141
Maximum,	3,900	65,230

DEFLECTION	Elastic limit,	.0481
	Maximum,	.3863
MODULUS OF ELASTICITY,		22,823,932

MECHANICAL LABORATORY, SCHOOL OF MECHANICAL ENGINEERING,
STATE COLLEGE OF KENTUCKY.
LEXINGTON, KY., 1895.

REPORT OF TRANSVERSE TESTS OF CAST IRON (ANNEALED).

Load applied, 4,600 lbs.

Laboratory No. 12A. Observers, J. W. MOORE, J. V. FAULKNER.

Dimensions.			Symbol.
Length,	12	ins.	I
Breadth,	1.022	"	b
Height,	1.015	"	h
Maximum fibre distance,	.5075	"	e
Moment of inertia,	.0890		I

Load.	Actual.	Per □″ in Outer Fibre.
Elastic limit,	2,300	39,333
Maximum,	4,600	79,666

DEFLECTION	Elastic limit,	.0523
	Maximum,	.8123
MODULUS OF ELASTICITY,		23,970,337

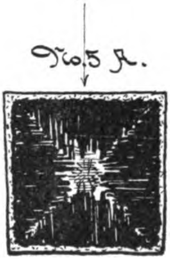
Laboratory No. 13A. Observers, J. W. MOORE, J. V. FAULKNER.

Load applied, 4,600 lbs.

Dimensions.			Symbol.
Length,	12	ins.	I
Breadth,	1.024	"	b
Height,	1.017	"	h
Maximum fibre distance,	.5085	"	e
Moment of inertia,	.0897	"	I

Load.	Actual.	Per □″ in Outer Fibre.
Elastic limit,	2,700	45,917
Maximum,	4,600	78,230

DEFLECTION	Elastic limit,	.0753
	Maximum,	.7785
MODULUS OF ELASTICITY,		21,453,542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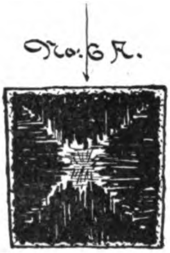
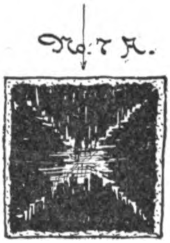

No. 6 A.

Fractures of Specimens subjected to transverse stresses.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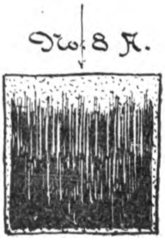
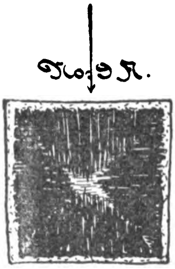
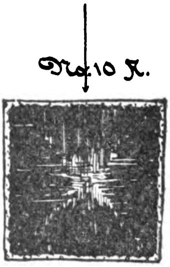
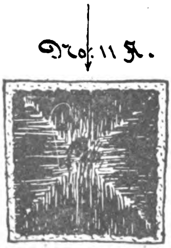

No. 8 A.


No. 9 A.


No. 10 A.

Fractures of Specimens subjected to transverse stresses.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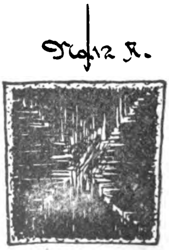

No. 12 A.

MECHANICAL LABORATORY, SCHOOL OF MECHANICAL ENGINEERING,
STATE COLLEGE OF KENTUCKY.

LEXINGTON, KY., 1895.

REPORT OF TRANSVERSE TESTS OF CAST IRON (ANNEALED).

Load applied, 4,650 lbs.

Laboratory No. 14A. Observers, J. W. MOORE, J. V. FAULKNER.

Dimensions.		Symbol.
Length,	12 ins.	I
Breadth,	1.019 "	b
Height,	1.015 "	h
Maximum fibre distance,	.5075 "	e
Moment of inertia,	.0885	I

Load.	Actual.	Per □″ in Outer Fibre.
Elastic limit,	2.300	39,567
Maximum,	4,650	79,134

DEFLECTION	Elastic limit,	.054
	Maximum,	.8483
MODULUS OF ELASTICITY,		21,300,000

Laboratory No. 15A. Observers, J. W. MOORE, J. V. FAULKNER.

Load applied, 4,500 lbs.

Dimensions.		Symbol.
Length,	12 ins.	I
Breadth,	1.023 "	b
Height,	1.026 "	h
Maximum fibre distance,	.513 "	e
Moment of inertia,	.0919	I

Load.	Actual.	Per □″ in Outer Fibre.
Elastic limit,	2,500	41,886
Maximum,	4,500	75,394

DEFLECTION	Elastic limit,	.01419
	Maximum,	.7317
MODULUS OF ELASTICITY,		22,000,000

MECHANICAL LABORATORY, SCHOOL OF MECHANICAL ENGINEERING,
STATE COLLEGE OF KENTUCKY.

LEXINGTON, KY., 1895.

REPORT OF TRANSVERSE TESTS OF CAST IRON (ANNEALED).

Load applied, 4,950 lbs.

Laboratory No. 16A. Observers, J. W. MOORE, J. V. FAULKNER.

Dimensions.			Symbol.
Length,	12	ins.	I
Breadth,	1.009	"	b
Height,	1.022	"	h
Maximum fibre distance,	.501	"	e
Moment of inertia,	.0897		I

Load.	Actual.	Per □″ in Outer Fibre.
Elastic limit,	2,600	44,434
Maximum,	4,900	84,595

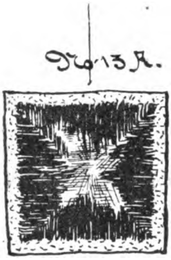
MODULUS OF ELASTICITY, 18,300,000

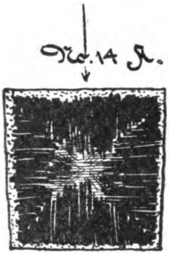
Laboratory No. 17A. Load applied, 4,400 lbs.

Dimensions.			Symbol.
Length,	12	ins.	I
Breadth,	1.017	"	b
Height,	1.017	"	h
Maximum fibre distance,	.5085	"	e
Moment of inertia,	.089		I

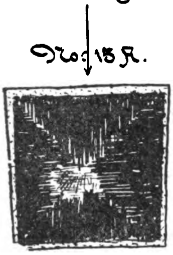
Load.	Actual.	Per □″ in Outer Fibre.
Elastic limit,	2,400	41,103
Maximum,	4,400	75,350

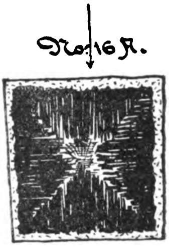
DEFLECTION { Elastic limit, .0513
DEFLECTION { Maximum, .379
MODULUS OF ELASTICITY, 18,900,000



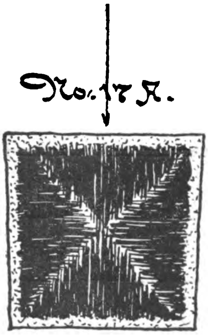


Fractures of Specimens
subjected to transverse stresses.





Fractures of Specimens
subjected to transverse stresses.



MECHANICAL LABORATORY, SCHOOL OF MECHANICAL ENGINEERING,
STATE COLLEGE OF KENTUCKY.

LEXINGTON, KY., 1895.

REPORT OF TRANSVERSE TESTS OF CAST IRON (REFINED).

Load applied, 2,200 lbs.

Laboratory No. 1B. Observers, J. W. MOORE, J. V. FAULKNER.

Dimensions.			Symbol.
Length,	12	ins.	I
Breadth,	1.058	"	b
Height,	1.038	"	h
Maximum fibre distance,	.519	"	e
Moment of inertia,	.0985		I

Load.	Actual.	Per □″ in Outer Fibre.
Maximum,	2,200	34,743

DEFLECTION, Maximum, .0497
MODULUS OF ELASTICITY, 13,000,000

Laboratory No. 2B. Load applied, 3,400 lbs.

Dimensions.			Symbol.
Length,	12	ins.	I
Breadth,	1.056	"	b
Height,	1.081	"	h
Maximum fibre distance,	.5405	"	e
Moment of inertia,	.106		I

Load.	Actual.	Per □″ in Outer Fibre.
Maximum,	3,400	50,807

MODULUS OF ELASTICITY, 16,200,000

MECHANICAL LABORATORY, SCHOOL OF MECHANICAL ENGINEERING,
STATE COLLEGE OF KENTUCKY.

LEXINGTON, KY., 1895.

REPORT OF TRANSVERSE TESTS OF CAST IRON (REFINED).

Load applied, 2,900 lbs.

Laboratory No. 3B. Observers, J. W. MOORE, J. V. FAULKNER.

Dimensions.			Symbol.
Length,	12	ins.	I
Breadth,	1.083	"	b
Height,	1.045	"	h
Maximum fibre distance,	.5225	"	e
Moment of inertia,	.1029		I

Load.	Actual.	Per □″ in Outer Fibre.
Maximum,	2,900	45,699

DEFLECTION, Maximum, .0473
MODULUS OF ELASTICITY, 19,200,000

REMARKS.—Elastic limit is not easily determined in the B set of specimens, and the Modulus of Elasticity is not entirely satisfactory.

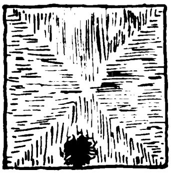
Laboratory No. 4B. Load applied, 3,300 lbs.

Dimensions.			Symbol.
Length,	12	ins.	I
Breadth,	1.052	"	b
Height,	1.077	"	h
Maximum fibre distance,	.5385	"	e
Moment of inertia,	.1095		I

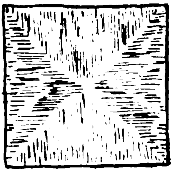
Load.	Actual.	Per □″ in Outer Fibre.
Maximum,	3,300	48,684

DEFLECTION, Maximum, .0492
MODULUS OF ELASTICITY, 14,200,000

No. 1 B

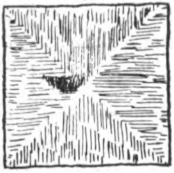


No. 2 B.

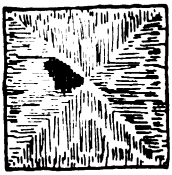


Fractures of Specimens subjected to transverse stresses.

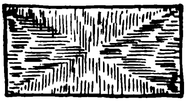
No. 3 B.



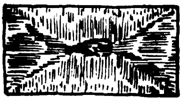
No. 4 B.



No. 1 C

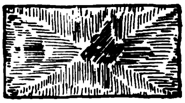


No. 2 C.

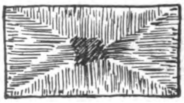


Fractures of Specimens subjected to transverse stresses.

No. 3 C.



No. 4 C.



MECHANICAL LABORATORY, SCHOOL OF MECHANICAL ENGINEERING,
STATE COLLEGE OF KENTUCKY.

LEXINGTON, KY., 1895.

REPORT OF TRANSVERSE TESTS OF CAST IRON (REFINED).

Load applied, 1,900 lbs.

Laboratory No. 1C. Observers, J. W. MOORE, J. V. FAULKNER.

Dimensions.			Symbol.
Length,	12	ins.	I
Breadth,	1.293	"	b
Height,	.687	"	h
Maximum fibre distance,	.3435	"	e
Moment of inertia,	.0348		I

Load.	Actual.	Per ☐″ in Outer Fibre.
Maximum,	1,900	56,286

MODULUS OF ELASTICITY, ... 14,800,000

Laboratory No. 2C. Load applied, 1,850 lbs.

Dimensions.			Symbol.
Length,	12	ins.	I
Breadth,	1.281	"	b
Height,	.673	"	h
Maximum fibre distance,	.3365	"	e
Moment of inertia,	.0325		I

Load.	Actual.	Per ☐″ in Outer Fibre.
Maximum,	1,850	57,463

DEFLECTION, Maximum, ...0848
MODULUS OF ELASTICITY, ... 22,200,000

MECHANICAL LABORATORY, SCHOOL OF MECHANICAL ENGINEERING,
STATE COLLEGE OF KENTUCKY.

LEXINGTON, KY., 1895.

REPORT OF TRANSVERSE TEST OF CAST IRON (REFINED).

Load applied, 2,000 lbs.

Laboratory No. 3C. Observers, J. W. MOORE, J. V. FAULKNER.

Dimensions.			Symbol.
Length,	12	ins.	I
Breadth,	1.313	"	b
Height,	.684	"	h
Maximum fibre distance,	.342	"	e
Moment of inertia,	.035		I

Load.	Actual.	Per □″ in Outer Fibre.
Maximum,	2,000	58,628

DEFLECTION, Maximum,	.0881
MODULUS OF ELASTICITY,	21,000,000

Laboratory No. 4C. Load applied, 1,850 lbs.

Dimensions.			Symbol.
Breadth,	1.31	in.	b
Height,	.644	"	h
Maximum fibre distance,	.322	"	e
Moment of inertia,	.0252	"	I

Load.	Actual.	Per □″ in Outer Fibre.
Maximum,	1,850	71,356

DEFLECTION, Maximum,	.0776
MODULUS OF ELASTICITY,	34,000,000

Below is a statement of physical properties of malleable cast iron as determined from the foregoing tests:

TRANSVERSE TESTS—ANNEALED.

Laboratory No.	Stress per Square Inch at Outermost Fibre at Elastic Limit.	Ultimate Stress per Square Inch at Outermost Fibre.
5A	38,400	63,980
6A	41,432	67,005
7A	35,162	70,324
9A	49,731	72,110
10A	47,973	82,239
11A	40,141	65,230
12A	39,333	78,666
13A	45,917	78,230
14A	39,567	79,134
15A	41,886	75,394
16A	44,434	84,595
17A	41,103	75,350
Average	42,089	74,354

TRANSVERSE TESTS—REFINED.

Laboratory No.	Ultimate Stress per Square Inch at Outermost Fibre.
1B	34,743
2B	58,070
3B	45,699
4B	48,684
1C	56,268
2C	57,463
3C	58,628
4C	71,356
Average	52,956

TRANSVERSE TESTS—ANNEALED.

Laboratory No.	Elastic Limit.	Ultimate Strength.	Maximum Deflection.	Modulus of Elasticity.
5A	2,400	4,000	.336	21,430,000
6A	2,600	4,200	.450	18,940,000
7A	2.100	4,200	.442	21,804,000
9A	3,000	4,350	.401	21,165 000
10A	2,800	4,800	.923	20,056,000
11A	2,400	3,900	.385	22,823,000
12A	2,300	4,600	.812	23,970,000
13A	2,700	4,600	.778	21,453,000
14A	2,300	4.650	.848	21,300,000
15A	2,500	4,500	.731	22,000,000
16A	2,600	4,900	. . .	18,300,000
17A	2,400	4,400	.379	18.900,000
Average, . .	2,508	4,425	5.894	21,000,000

TRANSVERSE TESTS—REFINED.

Laboratory No.	Elastic Limit.	Ultimate Strength.	Maximum Deflection.	Modulus of Elasticity.
1B	. . . .	2,200	. . . .	13,000,000
2B	. . . .	3,400	. . . .	16,200,000
3B	. . . .	2,900	. . . .	19,200,000
4B	. . . .	3,300	. . . .	14,200,000
Average, . .	. . . .	2,950	. . . .	15,650,000
1C	. . . .	1,900	. . . .	14,800,000
2C	. . . .	1,850	. . . .	22,200,000
3C	. . . .	2,000	. . . .	21,000,000
4C	. . . .	1,850	. . . .	34,000,000
Average, . .	. . . .	1,900	. . . .	23,000,000
Average of (1, 2, 3, 4) B, . .		2,950	. . . .	15,650,000
Average of (1, 2, 3, 4) C, . .		1,900	. . . .	23,000,000
General average, ...		2,435	. . . .	19,300,000

TENSIONAL TESTS—ANNEALED.

Laboratory No.	Stress per Square Inch at Elastic Limit.	Ultimate Strength per Square Inch.	Per Cent. of Elongation.	Modulus of Elasticity.
5	31,528	41,428	2.12	14,270 000
6	31,295	40,704	2.	14,225,000
7	31,528	41,257	1.5	24,000,000
9	34,060	39,364	1.5	13,000,000
10	31,528	40,571	2.12	14,285,000
11	28,450	23,098	2.15	12,300,000
12	30,898	44,101	2.	14,040,000
13	30,137	41,506	3.7	9,130,000
14	31,528	43,271	2.5	11,400,000
15	30,555	47,750	3.	12,200,000
16	31,581	46,600	3.96	14,335,000
17	31,581	44,045	1.5	9,550,000
18	28,750	36,050	.87	10,000,000
19	32,500	37,975	1.	12,500,000
20	30,768	34,948	.75	12,209,000
21	30,000	40,642	1.75	10,666,000
Average, . .	31,042	41,582	2.07	13,000,000

TENSIONAL TESTS—REFINED.

Laboratory No.	Ultimate Stress per Square Inch.
1, ...	21,469
2, ...	28,168
3, ...	20,000
4, ...	25,141
Average, ...	23,695

Specimen No. 8A was poured on a chill, and the sketch shows how the crystals arranged themselves perpendicular to the chill. The strength and ductility were very much increased.

The foregoing results show that the tensional strength of refined cast iron is increased about 80 per cent. by being annealed, also that the transverse strength is increased 80 per cent by being annealed.

The tensional modulus of elasticity was obtained from the formula:

$$\frac{S}{s} = E.$$

In which

S = Stress per unit.
s = Unit elongation.

The stress at outermost fibre was found by using formula:

$$\frac{SI}{c} = M.$$

In which

S = Stress at outermost fibre.
I = Moment of inertia of section, which in this case is $\frac{1}{12}$ bd^3.
c = Distance of outermost fibre from neutral axis.
M = Bending moment of section, which in this case is $\frac{1}{4}$ Wl.

The transverse modulus of elasticity was obtained from the formula:

$\triangle = \frac{1}{48} \times \frac{Wl^3}{EI}$. In which

$\triangle$ = Deflection.
W = Load.
l = Length of beam.
E = Modulus of elasticity.
I = Moment of inertia of section, which in this case = $\frac{1}{12}$ bd^3.

Therefore $E = \frac{1}{4} \times \frac{Wl}{bd^3} \triangle$ (1).

The values in the right-hand member of (1) were all obtained by measurement.

The deflection was obtained by noting the relative movement of two points, one of which was fastened to the upper stationary head of the testing machine and the other to the lower movable head. The readings were taken with a micrometer caliper.

The above results set forth very well the physical properties of malleable cast iron, about which we have very little definite knowledge.

JAMES H. WELLS.

BEHAVIOR OF IRON AT AN ABNORMALLY LOW TEMPERATURE.

THE behavior of iron at an abnormally low temperature formed the subject of a discourse by Prof. Steiger, of Prague, before the Zürich Congress, in 1895. The discourse embraces a short review of the older trustworthy investigations and a more detailed presentation of the experiments made by Steiner in 1891, and more recently by Dewar.

Steiner's experiments form a portion of the labors of a larger commission which was appointed by the government of Prague for the purpose of investigating the applicability of ingot iron in place of weld iron to bridge construction. These investigations included tensile and bending tests of weld iron as well as of Thomas and Martin ingot iron at the ordinary temperature of a room and at a low temperature down to —70° C. Liquid carbonic acid served for the production of cold according to two different methods. In the older method the test-piece as well as the ends of the jaw holding it were enveloped in a velvet bag, and liquid carbonic acid was introduced into the bag through a hose-like attachment. The solid carbonic acid formed was constantly replenished as required.

It executing a second series of experiments a glass cylinder was placed over the vertically fixed test-piece and the lower end of the cylinder closed by a cork dipped in fish-glue and an elastic layer of fish-glue mixed with a small quantity of chromium chloride applied to the cork. After inserting a thermometer alongside the test-piece, the cylinder was filled with ether, and the latter cooled to —60° C. by imbedding the cylinder in solid carbonic acid. This method, however, always caused the test-piece to break at the height of the level of the fluid.

The results of Steiner's tensile experiments are given in Table I. They show, in agreement with the experiments made at the Charlottenburg experimental station that, by cooling, the extensions at the stretching limit and in breaking are increased, and the elongation by rupture is reduced. The results of these experiments proved the magnitude of the influence of cold to be approximately alike foi Martin and Thomas ingot iron and greater than for weld iron.

TABLE I.—RESULTS OF STEINER'S TENSILE EXPERIMENTS.

Material.	Experimental temperature ° C.	Extensions Kilogrammes per Square Millimeter.		Elongation by Fracture. %.	Reduction of Cross-Section %
		Stretching Limit.	Fracture.		
Weld Iron, ...	+18.8	27.1	41.3	18.5	48.9
	—50.0	32.8	42.4	15.0	51.0
Martin Iron, ...	+25.0	24.8	40.1	30.5	62.3
	+25.0	26.7	41.2	30.5	64.0
	(—23.0)	26.4	40.7	(26.0)	61.2
	(—40.0)	27.2	42.2	——	62.6
	—40.0	31.8	43.7	17.0	60.0
Thomas Iron, ...	+25.0	26.2	38.1	30.5	69.4
	(+25.0)	25.4	37.9	27.0	69.1
	—50.0	27.3	40.1	20.0	67.6
	—50.0	32.8	40.9	17.0	67.7

In order to make possible a direct comparison of their results the bending experiments were executed in the same series of experiments under hammer blows of equal weight and equal height of fall. In these experiments the influence of cold was especially obvious upon the injured pieces, those of ingot iron and a few kinds of weld iron becoming absolutely brittle as glass, while with uninjured pieces essentially more favorable results were obtained. It was further shown that the material in an injured state is also more capable of resisting the influence of cold, the more it has been mechanically worked.

For the purpose of examining the fractured surfaces of the cooled test-pieces, which become immediately covered with hoar-frost, the fractured pieces were thrown into alcohol. From the texture of the fracture a molecular transposition by the cold could not be recognized with certainty, and it seems questionable to Steiner that a complete molecular change takes place because after thawing the pieces which had been cooled to —70° C. no unfavorable alterations could be recognized. Dewar has investigated the influence of cold (—182° C.) upon the tensile strength and the strength of resistance to shocks of different metals and upon the magnetic behavior of soft and hard steel. For the production of cold he used liquid oxygen. The tensile experiments were made with a lever-balance with wires about 2.5 millimeters in diameter and 50 millimeters long, and with small cast samples about 5 millimeters in diameter which were provided with ball heads. Loading was effected by a continuous flow of water into a vessel suspended to the long lever-arm of the machine. The test-pieces, together with the contrivances holding them, were placed in a silvered vacuum vessel which contained the liquid oxygen. A portion of the results obtained—average values of three to six separate experiments—are given in Table II. According to these results, all the metals in the form of wire showed greater tensile strength in the cold than at +15° C. The increase in strength is, according to the appended proportional figures, for iron over 100 per cent., and decreases to 26 per cent. for silver. After re-heating to +15° C. the samples which had been cooled to —182° C. showed no permanent change in their tensile strength. The results of the experiments with cast samples also showed greater tensile strength for tin, lead, soldering metal, and Wood's metal in a cooled state, the strength being twice to three times as great as at the ordinary temperature of a room. Furthermore, mercury at —182° C. acquired the same strength as bismuth and antimony, which, at the ordinary temperature of a room, is about half that of lead.

On the other hand, the behavior of zinc, bismuth, and antimony in a cooled state differed widely from the rest of the metals, their strength decreasing up to 50 per cent. Dewar seeks to explain this decrease in strength by the fact that the stresses set up in cooling such highly crystalline bodies probably weakens some set of cleavage planes of the crystals. The measurements of extension led only to the general observation that at the ordinary temperature of a room the capacity of stretching is about the same for tin and lead, while at —182° C. tin broke without scarcely any extension. Lead, on the other hand, suffered no appreciable loss in regard to its ductility.

TABLE II.—DEWAR'S INVESTIGATIONS REGARDING THE INFLUENCE OF COLD UPON THE TENSILE STRENGTH OF METALS IN KILOGRAMMES PER SQUARE MILLIMETER.

Condition of Material	Wires.							Cast Pieces.							
Temperature at the Test. ° C.	Soft Steel.	Iron.	Copper.	Brass.	German Silver.	Gold.	Silver.	Tin.	Lead.	Zinc.	Mercury.	Bismuth.	Antimony.	Soldering Metal.	Wood's Metal.
15	39	30	19	29	44	23.5	31	4.5	1.7	0.78	0	1.3	1 35	6.7	3.1
— 182	65	62	28	41	56	32	39	8.7	3.8	0.58	0 69	0.67	0.67	14.4	10.0
Proport'al figures,	167	206	147	141	127	136	126	193	224	74	. .	51	50	215	322

The experiments regarding resistance to shocks were executed by

Dewar by allowing spherical test-pieces to fall from a definite height upon iron plates. The results showed that in all cases the elastic resilience is increased by cooling. Furthermore, the diameter of the permanent flattening of the cooled lead balls was only about one-third of that of the pieces tested at the ordinary temperature of a room.

For the examination of the magnetic properties of soft and hard steel, Dewar used pieces of steel wire twenty-five to fifty millimetres long, separately as well as in bundles. The test-pieces were secured by means of copper clamps in a piece of wood, and together with the latter brought into the field of a magnetometer. Cooling was effected by placing upon the test-pieces cotton saturated with liquid oxygen, each test-piece being alternately cooled three to four times and again heated to the ordinary temperature of a room. The results of the experiments are compiled in Table III, the variations in per cent. being given which the magnetic moment previously determined at 15° C. suffered by cooling as well as by heating the permanent magnet.

TABLE III.—VARIATIONS IN THE MAGNETIC MOMENT OF STEEL BY REPEATED COOLING AND REHEATING.

Experiment No.	Material.	Experiment Series.	Variations in the Magnetic Moment in % of the Moment Determined in the Previous Series at 15° C. by	
			Cooling to — 182 C.	Reheating to + 15° C.
1	Hard Steel, 12.7 mm. long, 10.2 mm. diameter, ...	*a*	± 0	— 30
		b	+ 33	— 5
		c	+ 36	± 0
2	Soft Steel, ...	*a*	+ 12	— 28
		b	+ 51	± 0
		c	+ 51	± 0
3	Hard Steel, 26.2 mm. long, 10.2 mm. diameter, ...	*a*	— 24	— 43.4
		b	+ 23	± 0
		c	+ 23	± 0
4	Bundle of Nine Steel Wires, ...	*a*	+ 12.5	+ 3
		b	+ 38	— 2
		c	+ 30	± 0
		4 days later than *a*	+ 50	± 0

According to these results the magnetic power in the various magnets is changed by alternate cooling and reheating, at first in an entirely different manner, until finally a constant state of the magnet is attained at which, by cooling to — 182° C., all suffer an increase of 30 to 50 per cent. in the magnetic moment, and to which they return by reheating to + 15° C.

LETTERS TO THE EDITOR.

This department is set aside as an open door for communications upon all subjects pertaining to the physical properties of the materials of construction. We solicit letters from the colleges, private and governmental laboratories, both at home and abroad, and from all those interested in the field which we represent. It is desired that this department shall be the means of bringing forth and circulating amongst engineers and architects the knowledge gained in these various laboratories. And we shall hope to have it well filled with testing-room kinks, and practical facts of permanent value.

TETMAJER'S CRITERION AGAIN.

Editor Digest:—I fear Mr. Kent, in the July DIGEST, was more anxious to score a point than to arrive at facts. Neither Professor Tetmajer nor any one else ever proposed, so far as I am aware, to use his "quality-coefficient" alone as a criterion of acceptance. In the paragraph he quoted from my article in the January DIGEST, I speak of its use in determining "the working qualities of structural iron or steel." This limits its use in steel to the low-carbon steels of, let us say, a tensile strength of less than 70,000 lbs. per sq. in. Suppose we apply it to all steels from 55,000 to 70,000 lbs. tensile strength, with the limiting minimum product of 150,000 proposed by Mr. Kent. We should then be obliged to accept the following grades of material:

55,000 lbs. tensile strength with an elongation of 27.3 per cent.
60,000 " " " " " 25.0 "
65,000 " " " " " 23.1 "
70,000 " " " " " 21.4 "

Of course the engineer who draws the specification, would as now, set limits to the tensile strength, or at least he would set an upper limit to prevent the acceptance of high-carbon steel, and if he wished to make this limit 65,000 lbs. instead of 70,000 lbs. he could do so, and still use the criterion with profit.

Suppose we take the specifications recently put out by the Association of American Steel Manufacturers (adopted August 9th, 1895), where they give two grades of structural steel (omitting the rivet steel grade) as follows:

NAME OF GRADE.	TENSILE STRENGTH.	PER CENT. OF ELONGATION.
Soft Steel, ...	52,000 to 62,000	25
Medium Steel, ...	60,000 to 70,000	22

That is to say they are willing to furnish 62,000 lbs. of steel with an elongation of 25 per cent., or 70,000 lbs. of steel with an elongation of 22 per cent. The products of these are respectively 155,000 and 154,000. In other words they recognize the *justice* of the criterion in their own specifications. We might, therefore, justly demand 30 per cent. elongation on 52,000 steel, and 26 per cent. elongation on 60,000 lbs. steel, and *this is exactly what Tetmajer's criterion enables the engineer to do.* If steel is supplied between the limits of tensile strength of 60,000 and 70,000 lbs., the inspector working under Tetmajer's criterion would require the 60,000 lbs. material to elongate 26 per cent. while he would admit the 70,000 lbs. specimens on 22 per cent., whereas under the present practice he must demand as high an elongation for 70,000 lbs. as he can ask for the 60,000 lbs. material, which is on its face an absurdity.

Has not Mr. Kent assumed an utterly unreasonable and improbable use of the criterion, and then proceeded to demolish the criterion itself, because of this assumed senseless application of it?

But before his decision succeeded in embalming itself in cold type, the irony of fate has manifested itself by the formal recommendation by the Committee of the American Society of Civil Engineers of the adoption of the criterion, and this recommendation was published in the *Engineering News* (July 16th), of which Mr. Kent is one of the editors, even before his antecedent discussion had appeared in the DIGEST! Thus the Committee recommend, for all grades of structural steel from 56,000 to 74,000 pounds, that the

$$\text{“ Per cent. of elongation in 8 in.} = \frac{1{,}500{,}000}{\text{Ultimate Strength.}}$$

$$\text{Per cent. reduction of area} = \frac{2{,}800{,}000}{\text{Ultimate Strength.”}}$$

While this criterion serves very well between these limits of tensile strength, it is possible to use a formula which will apply through a much wider range. Thus, from Table 6A, p. 17, *Howe's Metallurgy* *of Steel,* we may plot the upper and lower "common limits of elongation," corresponding to a range of tensile strength from 50,000 to 120,000 pounds, as shown in Figure 1. On this diagram the locus of the Committee of the American Society of Civil Engineers is drawn, and also one proposed by the writer in his forthcoming work on the *Strength of Materials.*

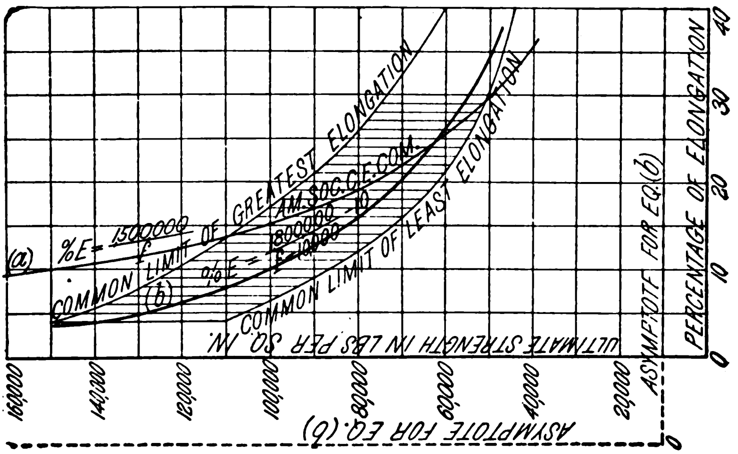


Fig. 1.

The formula he proposes is:

$$\text{Percentage of elongation} = \frac{1,800,000}{f-10,000} - 10 \text{——} (1)$$

where f=ultimate tensile strength in pounds per square inch. This gives a locus which lies at about the lower side of the middle third of the field, and hence is well below the middle of the field, at least for all values of tensile strength below 100,000 pounds per square inch.

With such a criterion as this, therefore, the question of what elongation to specify would be settled in advance, and it would only remain to determine what grade of steel was needed for the work in hand, in order to specify the proper tensile strength. In this modified form, therefore, this criterion would seem to have considerable value.

J. B. JOHNSON.

THE INFLUENCE OF FORM OF THREAD UPON SCREW BOLTS.

TO THE EDITOR:

DEAR SIR:—The above article in your July issue is certainly of considerable value. I presume it will claim the attention of many engineers, for the question of form of thread is by no means a settled one. To have sharp corners in any shaft, bolt, or beam under stress is an element of weakness, and usually is looked upon as very bad practice, yet our standard thread has sharp corners. If instead of mild steel the specimens had been "high carbon," a very different result would be recorded. In preparing test specimens of high carbon steel, the thread with rounded bottom is the only reliable one to ensure the breaking of specimen at middle. From actual experience I have repeatedly found the test-piece cut with Sellers thread broken in holder, although some ten per cent. greater in area than plain portion of piece—these very expensive failures led me to adopt a rounded bottom. Since this change there has been no breakage of thread recorded. Therefore, it is true for test results our standard is of an imperfect shape, and in some cases conducive to early failure. In built-up structures, where dependence on bolts is absolute, the form of thread that will endure continuous shocks, whether by tensile and torsional strains, or strains by impact, without failure, should be the one to consider. So far, our experience and investigations point to that with a curved root. Yours truly,

U. S. N.

LETTER TO EDITOR.

EMBREVILLE, TENN., August 31st, 1896.

DEAR SIR:—The question of testing coke for crushing and preparing test-pieces has recently come up at this point, and I should like very much to have some information as to method of preparation of specimens. I can find no literature bearing upon the subject, and have never seen account of any such tests. You will confer a favor by putting me in communication with any of your readers who are interested in this matter, or who can give me any information concerning same. Yours faithfully,

GUY R. JOHNSON, *Manager of the Embreville Estate.*

NOTES AND COMMENTS.

STRENGTH OF WOOD.

As a result of nearly 40,000 tests of timber made at the laboratory of the Washington University at St. Louis, under the direction of the Forestry Division of the Department of Agriculture, the following facts have been determined: Seasoned timber is about twice as strong as green timber, but well seasoned timber loses its strength with the absorption of moisture; timbers of large sections have equal strength per square inch with small ones when they are equally free from blemish; knots are as great a source of weakness in a column as in a beam; long leafed pine is stronger than the average oak, and bleeding timber does not impair its qualities. It is stated that a large amount of chestnut felled in Alabama for the tanbark was allowed to rot because its value for railroad ties was not known. The Division of Forestry called attention to the superiority of this timber for ties, and the wood is now so utilized, with a saving to that region alone of nearly $50,000 per year.—*Railway Engineering and Mechanics.*

THE RESISTANCE OF RIVETS.

Some time ago Mr. Dupuy was selected by the Ministry of Public Works, France, to make a special inquiry into the causes of deterioration of metallic structures. Experiments were first made on rivets, and a number of conclusions arrived at. A few of them are as follows: Rivets were found to not exactly fill the rivet holes, but to clamp the plates together with a pressure that gives rise to a resistance to sliding equivalent to a weld, which resistance is greater as the limit of the elasticity for rivet material is higher. The effort necessary to shear rivets per square inch of the sections to be sheared is not less than three-fourths of the tensile strength of the rivets per square inch. Mr. Dupuy draws from his conclusions some rules for bridge work, among which are the following: The calculation of riveting cannot be based upon the permissible stress in the test bars, the co-efficients of safety relating to the rivets not depending in any way on those adopted for the bars. A distance apart of 13 feet is recommended between cross girders, so as to reduce the stress on rivets. It is further concluded that if the secondary stress on rivets is not calculated and allowed for, the rivets may be expected to yield. In bridges of several spans continuous girders are to be preferred where there is no danger of settlement. With continuous girders the length of each boom from pier to pier does not appreciably change, and the riveting of the cross girders and rail-bearers is therefore less strained by the deformation of the bridge. This continuity should not extend over too many spans, as otherwise the efforts necessary to produce movements resulting from temperature changes becomes excessive. It is further concluded that in girders whose booms have a single web, and in those not horizontally braced above and below, vertical stiffners are desirable.—*American Manufacturer.*

AN INSTANCE OF SEGREGATION IN MILD STEEL.

A short time ago while a 16″ x ¾″ plate was going through the straightening rolls it broke square across, and with a fracture no mill would feel proud of. The plate was acid open hearth, and the makers have the best reputation for uniformity of product. The analysis of the steel made before rolling gave phos., .068; sulph., .049.

Drillings taken directly from the fracture gave phos., .124; sulph., .074.

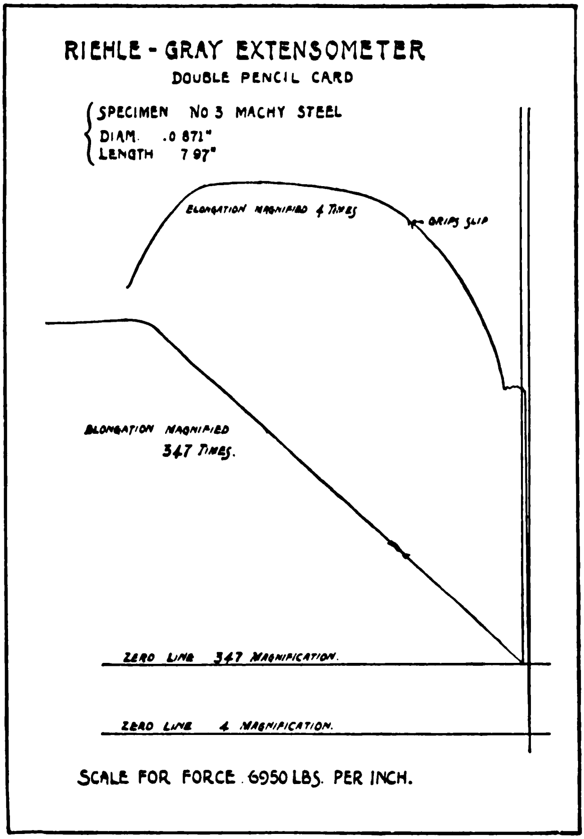
Drillings taken from a couple of inches back from the fracture gave phos., .110; sulph., .066.

Drillings taken about twelve or fifteen inches back from the fracture gave phos., .074; sulph., .066. This evidently shows segregation of these elements.

A peculiar feature is the low sulph. in the last determination.

Physical test of the plate made before shipment showed elastic limit, 41,330 lbs.; ultimate strength, 66,520; elongation, 25.5 per cent.; reduction, $56\frac{}{10}$ per cent.

DOUBLE CARD FROM PROF. GRAY'S EXTENSOMETER.



In our January number, page 17, there is an interesting description of the Riehlé-Gray Extensometer by Prof. Gray. To keep this matter fresh before our readers we have reproduced a double pencil card recently taken by Prof. Gray. It will be observed, that the magnification has a very wide limit, and the slightest irregularity in specimens or grips is truthfully recorded.—EDITOR.

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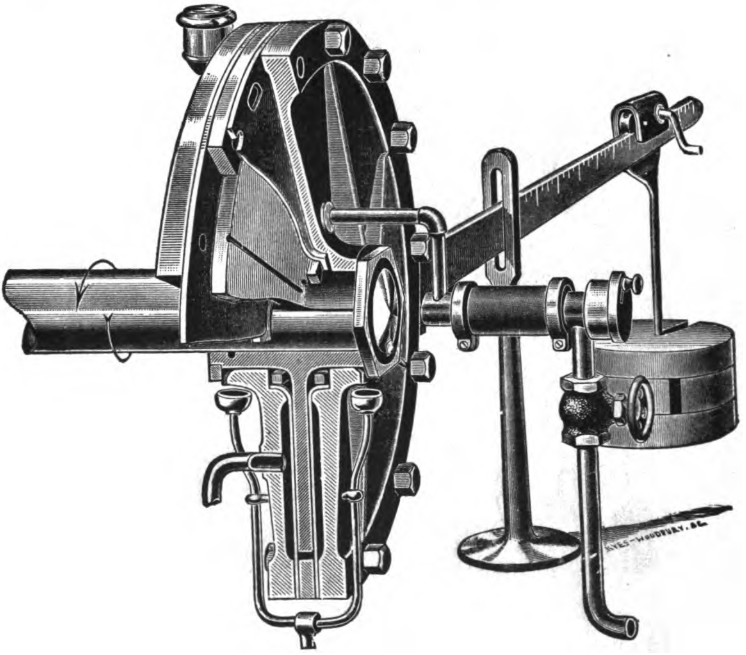

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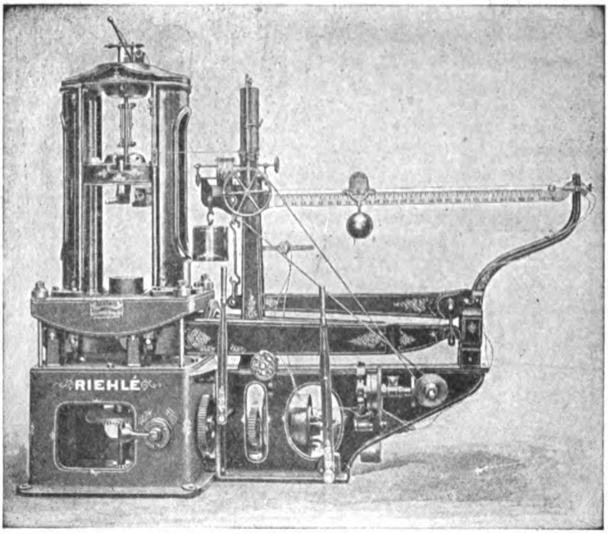

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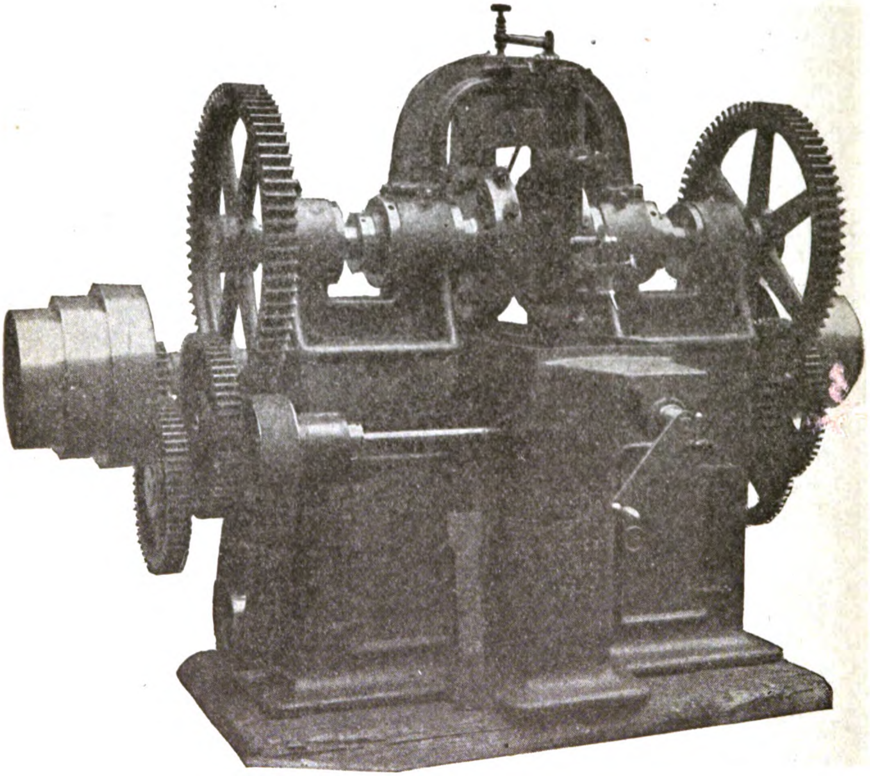

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